

# **The social and institutional aspects of industry-driven fruit fly area-wide management in Australian horticulture industries**

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and Charles Darwin University

By  
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## Statement

I, Heleen P. Kruger, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Sociology (Australian National University) and The Northern Institute (Charles Darwin University), is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

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Vir Pa, Ma en Gert

## Abstract

Queensland fruit fly (*Bactrocera tryoni*) (QFly) is one of Australia's most problematic horticultural pests. Key pesticides traditionally used to manage the pest, fenthion and dimethoate, have recently been restricted, resulting in area-wide management (AWM) of QFly becoming a key recommended practice. AWM involves management of the entire pest population by coordinating management strategies across all key pest sources throughout a geographical region. If successful, AWM requires fewer pesticides than traditional farm-by-farm approaches as it reduces the overall pest pressure in a region. It can potentially contribute to supporting market access to QFly-sensitive markets. Success depends on achieving and maintaining cooperation between a critical mass of landholders with QFly hosts on their land as unmanaged hosts provide breeding places for QFly. The increased push for AWM coincides with state governments tending to reduce direct on-ground support for pest management. It is increasingly up to local industries to take the reins of implementing AWM programs.

A considerable literature about AWM is available, but it focuses mainly on technical and economic aspects. This research investigated the social and institutional aspects of industry-driven AWM programs based on two research questions: (1) What social and institutional factors influence the success of industry-driven AWM at the local level and how can success be maximised?; and (2) What are the main constraints to an enabling environment for industry-driven AWM implementation and how can these be mitigated?

Three case studies, together with literature about socio-ecological systems, were explored to answer question 1. This involved 43 semi-structured interviews, three focus groups and a grower survey involving 98 respondents across the cases. Question 2 was answered based on 33 semi-structured interviews with people operating in the broader QFly management innovation system, representing the technological, institutional, organisational and

operational aspects of the QFly domain. These findings together with the grower survey results were analysed through the lens of Agricultural Innovation Systems thinking.

The research found that the feasibility of industry-driven AWM depends on factors at the local level and within the broader QFly management innovation system. Locally, a social profile favourable to AWM includes a relatively homogenous grower community; high levels of social capital; existing opportunities to monitor compliance; and a high ratio between those who have an incentive to manage QFly and those who do not. As every region is unique, AWM is best approached through adaptive co-management to bolster local QFly knowledge and support a common narrative and adaptive capacity. This involves 'learning by doing' and drawing on different knowledge systems including QFly biology and behaviour; market access; community engagement; and different forms of local knowledge. Market access requirements are best seen as 'bolt-on' components.

To carry out adaptive co-management, local industries need to be able to readily access the needed knowledge, capabilities and resources. The broader QFly management innovation system needs to be responsive to meeting these needs. Training for key local stakeholders can assist in overcoming limited local capacities. This work found that in the multi-level biosecurity world, the local level can easily become disconnected. Knowledge brokers and interconnected innovation platforms can ensure strong two-way information flow between local programs and other players, such as policy-makers, researchers and market access personnel. Other key difficulties to local industries include the reliance on voluntary approaches for securing wide-spread support and establishing a sustainable income. Complementary policy mechanisms tailored to local conditions to back-up industry-driven approaches are recommended. This research makes an important contribution to successful future QFly management by complementing prevailing high investment in improving QFly management technologies.





# Table of contents

Acronyms .....	11
Chapter 1. Introduction – Situating the problem.....	13
1.1 Introduction.....	13
1.2 Literature review about AWM.....	16
1.2.1 Social and institutional dimensions of AWM.....	19
1.3 This study.....	23
1.4 AWM as an action situation.....	26
1.4.1 The influence of QFly behaviour, biology & ecology on QFly pressure.....	29
1.4.2 The social and political context of plant biosecurity.....	30
1.4.3 The economic context of Australian horticulture .....	38
1.4.4 QFly management governance context .....	41
1.5 Summary .....	46
Chapter 2. Theoretical foundation and research approach.....	49
2.1 Introduction.....	49
2.2 The theoretical underpinnings of Phase 1 .....	49
2.2.1 Socio-ecological systems .....	50
2.2.2 Community collaboration .....	58
2.3 The theoretical underpinnings of Phase 2 .....	61
2.3.1 Agricultural Innovation Systems.....	62
2.3.2 The functional-structural analysis approach.....	67
2.4 Methods .....	72
2.4.1 Phase 1 – Case study research.....	72
2.4.2 Phase 2 – Semi-structured interviews about the institutional context.....	78
2.4.3 Phases 1 and 2 – Grower survey.....	83

2.5 Ethics .....	88
Chapter 3. The case studies .....	91
3.1 Central Burnett (Queensland) .....	92
3.1.1 Regional and grower community profile .....	92
3.1.2 History .....	94
3.1.3 Local organisation .....	94
3.1.4 Securing local cooperation .....	95
3.1.5 Market access .....	96
3.2 The Riverina (New South Wales) .....	97
3.2.1 Regional and grower community profile .....	97
3.2.2 History .....	99
3.2.3 Local organisation .....	100
3.2.4 Securing local cooperation .....	101
3.2.5 Market access .....	102
3.3 Young-Harden (New South Wales) .....	103
3.3.1 Regional and grower community profile .....	103
3.3.2 History .....	105
3.3.3 Local organisation .....	105
3.3.4 Securing cooperation .....	106
3.3.5 Market access .....	107
Chapter 4. Publications .....	109
4.1 Article 1. Designing local institutions for cooperative pest management to underpin market access: the case of industry-driven fruit fly area-wide management .....	109
4.2 Article 2. Adaptive co-management for collaborative commercial pest management: the case of industry-driven fruit fly area-wide management .....	134

4.3 Article 3. ‘Smart regulation’ and community collaboration in Australia’s modern biosecurity context.....	147
4.4 Article 4. Creating an enabling environment for industry-driven pest suppression: the case of suppressing Queensland Fruit Fly through area-wide management.....	178
4.5 Article 5. Helping local industries help themselves in a multi-level biosecurity world - Dealing with the impact of horticultural pests in the trade arena.....	189
Chapter 5. Conclusion.....	201
5.1 Introduction.....	201
5.2 A summary of the research’s contribution to AWM literature.....	202
5.2.1 Principle 1. The local social profile influences the prospects of successful AWM .....	206
5.2.2 Principle 2. AWM needs to be based on adaptive co-management.....	209
5.2.3 Principle 3. Local industries need help to help themselves.....	214
5.2.4 Principle 4. AWM programs need strong two-way connectivity with the broader QFly management innovation system .....	217
5.2.5 Principle 5. Industry-driven AWM programs need institutional adjustment .....	220
5.3 Other implications for social theory .....	225
5.3.1 Contributions to the SES literature .....	226
5.3.2 Contributions to the social sciences biosecurity literature .....	227
5.4 Recommendations for further research.....	232
References .....	235
Appendices.....	267
Appendix 1. Questions for Phase 1 case study interviews.....	268
Appendix 2. List of knowledge, capabilities and resources required for local industries to achieve fruit fly AWM.....	269
Appendix 3. Grower survey questions.....	274

Appendix 4. Phase 2 interview questions .....	293
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## List of boxes

Box 1. Overview of the journal articles produced .....	24
Box 2. Central Burnett – An example of adaptive co-management for fruit fly AWM.....	212

## List of figures

Figure 1. Applying the socio-ecological systems framework as a lens for QFly AWM (adapted from McGinnis and Ostrom, 2014) .....	27
Figure 2. Orchards adjacent to town areas in Mundubbera (left) and Leeton (right) .....	30
Figure 3. An overview of the case study locations .....	91
Figure 4. The Central Burnett district.....	93
Figure 5. The Riverina area .....	98
Figure 6. The Young-Harden region .....	104
Figure 7. The ideal industry-driven AWM situation.....	204

## List of tables

Table 1. Overlapping themes between adaptive co-management and innovation systems (including AIS). .....	66
Table 2. The representation and number of Phase 2 interviewees.....	79
Table 3. Grower survey response rates .....	87

# Acronyms

<b>ABARES</b>	Australian Bureau of Agricultural and Resource Economics and Sciences
<b>AIS</b>	Agricultural innovation systems
<b>ALPP</b>	Areas of low pest prevalence
<b>AWM</b>	Area-wide management
<b>CSIRO</b>	Commonwealth Scientific and Industrial Research Organisation
<b>DAWR</b>	Department of Agriculture and Water Resources
<b>FFEZ</b>	Fruit Fly Exclusion Zone
<b>HIA</b>	Horticulture Australia Innovation
<b>IPM</b>	Integrated pest management
<b>ICA</b>	Interstate Certification Assurance
<b>IPPC</b>	International Plant Protection Convention
<b>LGA</b>	Local government area
<b>NFFC</b>	National Fruit Fly Council
<b>NFFS</b>	Draft National Fruit Fly Strategy
<b>NRM</b>	Natural resource management
<b>NSW DPI</b>	New South Wales Department of Primary Industries
<b>PBCRC</b>	Plant Biosecurity Cooperative Research Centre
<b>PFA</b>	Pest free areas
<b>PHA</b>	Plant Health Australia
<b>QDPI</b>	Queensland Department of Primary Industries
<b>RBI</b>	Riverina Biosecurity Incorporated
<b>SES</b>	Socio-ecological systems
<b>SIT</b>	Sterile insect technique
<b>WTO</b>	World Trade Organisation



# Chapter 1. Introduction – Situating the problem

## 1.1 Introduction

Pests present a multi-faceted challenge to sustainable food production and they are spreading at an increasing rate related to the growing movement of people and goods across borders (Maye et al., 2012). Insect pests lower global food production by an estimated 14 per cent, despite the application of three million tonnes of pesticides annually (Pimentel, 2007). Several pests also cause restrictions to market access or necessitate costly preventative phytosanitary measures to avoid pest spread (Dibden et al., 2011; Quinlan, 2004). Moreover, increased concerns about the negative impacts of pesticides limit the use of certain chemicals that food producers previously relied upon to manage pests (Mumford, 2000) thereby limiting the control options available to food producers.

These conditions call for innovation in pest management approaches. This thesis focuses on one such approach, namely area-wide management (AWM). AWM involves tackling the entire pest population across a region in a coordinated fashion. If successfully done, it lowers the need for applying pesticides. However, pests are traditionally approached as a purely technical issue that can be solved through technological means. As the success of AWM is dependent on sustained collaboration between a range of people, this thesis extends this technocratic problem-solving approach by investigating the social and institutional aspects of AWM, especially when these ventures are industry-driven. In this thesis, institutions are defined in a broad sense as the rules, norms, or strategies that create incentives for certain behaviours in repetitive situations (Ostrom, 2005). They are the prescriptions that stipulate what actions are required, permitted, or forbidden in particular circumstances. In other words, institutions encompass the formal and informal mechanisms in play that determine how people do things in particular situations and why they do them one way rather than another (Marshall, 2013).

This study is timely as in several countries there is an increasing push for many local agricultural industries to be less dependent on direct government support and be more self-reliant (Cheshire and Lawrence, 2005), including for the management of established pests (Donaldson, 2013). AWM is, in this context, a highly salient example of the challenges inherent in industry-driven approaches to managing pests. This work focuses on a specific kind of pest, namely Queensland fruit fly (*Bactrocera tryoni*) (QFly). Yet, many of the insights gained here have broader application to other forms of rural stakeholder cooperation and area-wide pest management.

QFly forms part of the fruit fly family *Tephritidae*, or true fruit flies, which are the world's most significant commercial horticultural pests. Every major fruit and vegetable growing country has programs in place to deal with members of this insect family (Malavasi, 2014). Fruit fly presence limits national and international market access, causes production losses and imposes costs for pre- and post-harvest treatments (Qin et al., 2015; White and Elson-Harris, 1992). The total cost across the globe is estimated at US\$2 billion every year, including impacts on production, harvesting, packing and marketing (Malavasi, 2014).

The two species that have the most impact on Australian horticultural industries are QFly and Mediterranean fruit fly (*Ceratitis capitata*) (MedFly). Most commodities of Australia's estimated AUS\$9 billion horticultural industry (ABS, 2014b) are susceptible to varying degrees (Plant Biosecurity CRC, 2015). Between 2003 and 2008, the Australian horticultural industry and government invested more than AUS\$128 million in the management of fruit flies and reducing their impact on trade. This does not include the expenditure of growers in fruit fly endemic areas to prevent fruit fly infestation and deliver a marketable product (NFFS Implementation Committee, 2009).

QFly was chosen as the focus of this study as it has become more prevalent and problematic in certain parts of south-east Australia in recent years (Dominiak et al., 2015).



As this pest is not found anywhere else in the world, other than in certain areas on the eastern side of Australia and some South Pacific islands (Clarke et al., 2011), many horticulture importing countries impose strict requirements to ensure Australian produce from affected areas does not become a source of QFly infestation. Two factors exacerbate this challenge to horticulture growers in affected regions.

First, most state governments in Australia have traditionally been key contributors in performing and supporting on-ground operations to control fruit fly or prevent it from establishing in certain regions. However, there is increasingly an expectation that industry will play the leading role in funding and managing QFly control programs, often after increased fruit fly pressure renders sustained investment in on-ground operational activities no longer economically viable (e.g. NSW DPI, 2012; Victoria State Government, 2015).

Second, the use of two key pesticides—fenthion and dimethoate—has recently been restricted (APVMA, 2012; Florec et al., 2013). Many growers have traditionally used these pesticides to control fruit fly, as they are relatively low-cost, easy-to-apply, single-kill-step measures (Dominiak and Ekman, 2013; Clarke et al., 2011). The review of fenthion started in 1998 following concerns about the environment, human health, food residues and trade. It ended in October 2014, with the Australian Pesticides and Veterinary Medicines Authority (APVMA) cancelling active approvals and product registrations, with only very limited use of the chemical allowed. A phase-out period of products containing fenthion was allowed until October 2015 (APVMA, 2014). While the dimethoate review is still in progress, the use of this chemical has been restricted since October 2011 after a toxicology assessment revealed dietary risks (APVMA, 2016). Industry is now required to identify alternative ways to manage fruit fly. AWM is seen as a key alternative approach to manage fruit fly without reliance on heavy chemicals (PHA, 2008; Yu, 2006; Lloyd et al., 2010).

## 1.2 Literature review about AWM

Traditional approaches to pest management usually involve a reactive approach by landholders where problems are addressed farm-by-farm or orchard-by-orchard as pests arise. In other words, only small portions of the pest population are controlled at a time (Hendrichs et al., 2007). The difficulty with mobile pests, such as fruit fly, is that nearby untreated areas, such as from backyards, derelict orchards and wild hosts, become sources of re-infestation (Vreysen et al., 2007a; Hendrichs et al., 2007; Klassen, 2005). Hence, the uncoordinated endeavours by individual landholders are normally sub-optimal for effective management. Uniform suppression of the total pest population across a region is more effective in achieving lower pest pressures than a higher level of suppression on individual farms (Vargas et al., 2008; Yu and Leung, 2006).

AWM encompasses pest management strategies that are used over a wide geographical area, involving synchronised pest control activities across the whole area to reduce a pest below economic threat levels or to completely eradicate it (Elliott et al., 2008). In the context of fruit flies, this includes commercial horticulture operations and non-commercial settings described above (Vreysen et al., 2007c). The underlying principle of AWM is to prevent any places becoming refugia or breeding spots for the pest, which can lead to new population levels that cause concern (Klassen, 2004).

The application of an area-wide approach to controlling insects is not a new invention. It can be traced back to various historic events, such as dealing with locust plagues over the last two millennia in China and human diseases spread by insect vectors, for example mosquitos in parts of southern Europe and north America, (Hendrichs et al., 2007; Klassen, 2004). Currently AWM programs exist or have been trialled across the world, including in Argentina, Australia, Brazil, Chile, Central America, Israel, Mexico, South

Africa, Thailand, Tunisia and the United States. It is used to control a range of pests including citrus greening, codling moth, locusts, pink bollworm, ticks and tsetse fly.

A sizable body of literature exists in relation to AWM (for example, Pimentel, 2007; Lindquist, 2000; Klassen, 2005; Elliott et al., 2008; Dyck et al., 2005; Yu, 2006), and fruit fly AWM in particular (for example, Lloyd et al., 2010; Florec et al., 2010; Vargas et al., 2010; Jang et al., 2006; Prokopy et al., 2003; Orankanok et al., 2007; Dowell et al., 2000; Gonzalez and Troncoso, 2007). However, the great majority of the fruit fly AWM literature focuses on the technical and economic aspects of AWM, with limited attention given to the social and institutional aspects (exceptions include Mau et al., 2007; Reyes et al., 2007; Pambo et al., 2015). This is a significant gap, especially given that these programs comprise various social and institutional components which are recognised as having considerable impact on the success of AWM (Klassen, 2005; Hendrichs et al., 2007). In particular, to be successful, AWM requires the cooperation of a broad range of stakeholders, locally and beyond. The key social and institutional requirements for AWM identified in literature are discussed in the next sub-section.

Several benefit-cost analyses have shown that fruit fly AWM can be cost-effective (Kalang Consultancy Services, 2008; Ha et al., 2010; Yu, 2006; Mumford, 2004). Proponents of AWM argue that it promises great advantages in terms of reducing the need for pesticides and therefore having less impact on the environment and human health, including preventing insecticide resistance (Hendrichs et al., 2007). In the context of QFly management, AWM programs are based on softer control techniques such as protein baits, orchard hygiene, inspections and sometimes male annihilation technique (Jessup et al., 2007). This could be further supplemented by integrated pest management activities (Hendrichs et al., 2007). For example, biological control using fruit fly parasitoids, treatment of overwintering sites, planting and treating highly attractive hosts on the perimeter of commercial crops, removing unmanaged hosts such as derelict orchards or

wild hosts, fruit sanitation, and quarantine regulations to restrict movement of host produce into the AWM area (Lloyd, 2007).

AWM also enables the use of technologies that are generally not cost-effective to individual growers, such as sterile insect technique (SIT) (Klassen, 2004). SIT involves a type of birth control, where large numbers of a target species are reared, exposed to gamma rays to cause sexual sterility and then released in the target region. Sterile males mate with wild females preventing the females from reproducing (Klassen and Curtis, 2005). SIT is typically applied on an area-wide basis complemented by other control technologies (Klassen, 2005). Large investments are currently made in Australia to strengthen the use of SIT to manage QFly through a research and development consortium called SITplus worth almost AUS\$22 million (HIA, 2015).

Regional characteristics influence the cost of AWM. Characteristics that minimise costs include being adjacent to naturally occurring barriers (Florec et al., 2010; Sharov, 2004), such as hot dry areas, mountain ranges or large bodies of water, or regions with unfavourable climates (Gonzalez and Troncoso, 2007). Other factors that impact on the cost of AWM in an area include the production value of commercial hosts, the extent of non-crop hosts (such as backyard fruit trees, derelict orchards, fruiting trees in the wild) and the type of control best suited for the landscape. QFly is known to be abundant in many urban areas (Clarke et al., 2011) as temperature and moisture levels are generally more favourable to QFly here than nearby rural areas, especially if irrigation is used in towns (Dominiak et al., 2006).

AWM can be applied to achieve different goals, such as pest suppression, or it can be included as a formal phytosanitary measure in the trade context such as maintaining pest free areas or areas of low pest prevalence. The latter two are formally defined by the International Plant Protection Convention as follows:

- Pest free areas (PFAs) – *Area[s] in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained* (IPPC, 2013: , p17).
- Areas of low pest prevalence (ALPPs) – *Area[s], whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures* (IPPC, 2013: p10).

AWM is also viewed as a good candidate to include in systems approaches for market access (Jamieson et al., 2013; Dominiak et al., 2015). Systems approaches are formally defined as ‘*the integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests*’ (IPPC, 2013: p22).

However, implementing AWM is challenging as fruit fly management exhibits many characteristics of a ‘wicked problem’. As will become clear throughout this thesis, the fruit fly problem involves many interdependencies; is multi-causal, constantly changing and socially complex; does not sit clearly within the responsibility of one stakeholder group; and requires behavioural change (Termeer et al., 2013; Australian Public Service Commission, 2007). These issues are resistant to policy interventions targeted at a single level in, for example, the jurisdictional, spatial or institutional scales or when short-term timeframes are involved (Termeer et al., 2013; Cash et al., 2006). Hence the social and institutional aspects of wicked problems are a key component of identifying and solving such problems.

### **1.2.1 Social and institutional dimensions of AWM**

AWM needs effective partnerships, such as multi-institutional strategic collaborations (Reyes et al., 2007), involving stakeholders with diverse and interdependent backgrounds

that can contribute to different aspects of the program (Mau et al., 2007) and who are committed to achieving success (Elliott et al., 2008; Vreysen et al., 2007a). The relationship between local program management structures and higher level governance has also received some attention. For example, Vreysen et al. (2007a) identified that the management structure of successful programs tended to be flexible and independent with high financial and political autonomy enabling quick decision-making. Government interference through regulation and bureaucratic rules is minimal, but governments are sufficiently engaged to assist in emergencies. However, AWM also requires legal support to operate, such as regulations that enable access to private property (Klassen, 2005).

Mumford (2000) identify a lack of public participation as the main problem undermining the success of AWM programs. Yet, the cost of public relations is easily overlooked in the estimated cost of proposed pest control programs (Yu, 2006). Maintaining enthusiasm and interest from growers and other local stakeholders, such as crop consultants, and the broader industry, is a key challenge to the sustainability of AWM (Ferguson and Miles, 2002). Several authors refer to the ‘weakest link’ or ‘weaker links’ phenomena in relation to management of pests that are mobile, as the level of pest control is set by those contributors who invest the least in pest management (Perrings et al., 2002; Burnett, 2006; Florec et al., 2013).

Social and institutional factors that contribute to grower cooperation include well-functioning AWM programs, including trust-based extension services (Pambo et al., 2015; Ferguson and Miles, 2002). Cooperation from Darling Downs cotton growers in the Helicoverpa AWM program was assisted by the use of local experience and locally-gathered data; grower-to-grower communication; and managing grower expectations (Ferguson and Miles, 2002). Barnes (2007) found that cultural factors can have a significant influence on grower cooperation. Areas with different cultures, languages, crop types and diverse

outlooks on farming practices may make grower coordination and cooperation more challenging (Barnes, 2007; Yu, 2006).

When town people do not understand the importance of fruit fly control it makes the implementation of these programs considerably more difficult (Jessup et al., 2007). AWM programs must meet the concerns of the urban populations to prevent adverse reactions and to encourage cooperation. People affected by AWM programs and to whom the economic impact of the program is not their primary interest are often concerned about other perceived possible impacts, such as on the environment or human health (Klassen, 2005). Community engagement needs to start well before an AWM program commences to solicit wide support and prevent backlash from often well-intentioned, but ill-informed people. Public relations programs need to be well-resourced throughout the lifetime of an AWM program to maintain wide-spread awareness and support. Such programs need to be adjusted by taking into consideration the local cultural profile (Vreysen et al., 2007a). There is a need to create fora that allow for effective two-way communication with the community, and community representatives need to be engaged in the programs' decision-making processes (Klassen, 2005).

Furthermore, economists argue that the attributes of a natural resource influence how users and other relevant parties respond to maintaining it, especially in relation to excludability and subtractability. Excludability refers to the ability to exclude others from the benefits of a resource. Subtractability refers to whether consumption of the resource lowers the availability of the resource to others (Ostrom, 2005). Fruit fly management is seen as an industry good, as the main benefits of pest control are directly and fully apportioned to certain industries or farmers (Abdalla et al., 2012). However, related to the 'weaker link' public good argument (Perrings et al., 2002), it can be argued that the absence (or low prevalence) of QFly in the context of AWM resembles a common-pool resource, i.e. a resource with low excludability and high subtractability. Landholders who are not

controlling the pest on their properties are reducing resource benefits to farmers who are carrying out pest control, as the former provides breeding spots for the pest which harms the resource for all users (implying high subtractability). Hence, the social dilemmas of free-riding and 'opting-out' associated with common-pool resources also apply in the context of mobile pest management and must be considered in AWM program design. For example, if a critical mass of landholders is following recommended practice, thereby lowering QFly prevalence in the region, those who are not following suit cannot be excluded from the benefits, i.e. they are free-riding. This may provide an incentive not to invest in pest control. Likewise, landholders witnessing others doing little to address QFly on their properties may have a perverse incentive to use this observation as an 'opt out clause' by asking 'Why should I control the pest if they don't?' (Ostrom, 1990; Anderies et al., 2004). Several others (e.g. Reid et al., 2009; Davis and Harrison, 1999; Ferguson and Miles, 2002) also identified that one stakeholder group's lack of pest control can discourage other landholders from controlling the pest on their properties.

However, despite being negatively affected by risk contributors who under-invest in pest management, those who invest more might still enjoy better crop protection than those investing less (Burnett, 2006). This implies that landholders who are economically or otherwise negatively affected by QFly still have an incentive to manage the pest on their land, regardless of what others do. Landholders who have little incentive to manage QFly and who would have to do so for the greater good of the local horticultural industry can be expected to be more likely to 'opt out' if they witness QFly not being addressed on land elsewhere.

Scholars have found that the biophysical attributes of natural resources also influence the ability to achieve a resource management program design that is well supported by stakeholders. Two main biophysical attributes that hinder collective action between resource users include resource mobility and storage (Agrawal, 2001; Ostrom, 2005;



Poteete et al., 2010). Fruit fly has high mobility attributes as it is a mobile pest and it can also ‘hitchhike’ with travellers into fruit fly sensitive areas (Dominiak and Coombes, 2009). In terms of storage capability, the benefits of having no or low fruit fly prevalence can also not be stored, such as water in a lake or holding on to a common herd of cattle. Mobility and lack of storage capability increase the transaction costs of finding suitable solutions for resource maintenance as these factors reduce the predictability of resource availability (Agrawal, 2001; Poteete et al., 2010).

To summarise, the social and institutional aspects are likely to be more significant when AWM is industry-driven. The success of AWM will be influenced by the difficulty of local industries to find suitable partners to support them in their endeavours to achieve AWM. Cooperation from risk contributors is challenged by the common-pool nature, the mobility of fruit fly and the lack of storage capability of no/low fruit fly prevalence. It suggests that the institutional context for QFly management needs to be designed specifically to support local industries to achieve AWM.

### **1.3 This study**

The research presented in this thesis examines the social and institutional aspects of industry-driven AWM that impact on the success of these ventures. The empirical context is the Australian horticultural sector. This study has two key research questions that have been answered across five journal articles (see Box 1):

1. What social and institutional factors influence the success of industry-driven AWM at the local level and how can success be maximised? (Phase 1)
2. What are the main constraints to an enabling environment for industry-driven AWM implementation and how can these be mitigated? (Phase 2)

## Box 1. Overview of the journal articles produced

### PHASE 1

**Article 1: Designing local institutions for cooperative pest management to underpin market access: the case of industry-driven area-wide fruit fly management.** (Published in the International Journal of the Commons.) In this article Ostrom's design principles for robust common-pool resource institutions (Anderies et al., 2004; Poteete et al., 2010; Cox et al., 2010; Ostrom, 1990) are applied to case study findings to demonstrate the important influence of regional communities' social profile on their ability to achieve AWM.

**Article 2: Adaptive co-management for collaborative commercial pest management: the case of industry-driven fruit fly area-wide management.** (Published in the International Journal of Pest Management.) Adaptive co-management provides a pragmatic way for local industries to initiate local collective fruit fly management initiatives. Key principles contained in the adaptive co-management literature are used as a lens through which the case study findings are explored to better understand what enables AWM.

### PHASE 2

**Article 3: "Smart regulation" and community collaboration in Australia's modern biosecurity context** (under review with the journal Rural Society – the first round of reviewers' feedback has been incorporated). A key challenge to industry-driven AWM is achieving wide-spread voluntary cooperation amongst fruit fly risk contributors, including growers, town residents and other landholders. Case study findings; theoretical considerations about the role of community in biosecurity; and experiences elsewhere contributed to identifying four options for dealing with this challenge.

**Article 4: Creating an enabling environment for industry-driven pest suppression: the case of suppressing Queensland fruit fly through area-wide management.** (Published in the Agricultural Systems journal.) In an era of limited on-ground government support institutional innovation is required to ensure that the QFly management innovation system is designed such that it makes readily available the knowledge, capabilities and resources that local industries need to

achieve AWM. Agricultural innovation systems (AIS) thinking is applied to identify how to create an enabling institutional environment that will support local industries in their quest to achieve QFly suppression through AWM. The main blocking mechanisms in the current support system are identified and they guide pinpointing key opportunities for improvement based on a structural-functional analysis (Jacobsson and Bergek, 2011; Bergek et al., 2008; Wieczorek and Hekkert, 2012).

**Article 5: Helping local industries help themselves in a multi-level biosecurity world –**

**Dealing with the impact of horticultural pests in the trade arena** (Published in NJAS

(Wageningen Journal of Life Sciences).) This paper applies the same approach as article 4, but with a key focus on achieving market access using a systems approach involving AWM.

The first question is explored in Phase 1 of the research, which involves a case study approach in three diverse areas in New South Wales and Queensland where AWM for QFly has been implemented (or attempted). This comparative analysis is undertaken to understand, from a social and institutional perspective, what enables or hinders progress in and the success of these endeavours. Findings are considered by drawing on the social-ecological systems framework (Figure 1) (Ostrom, 2007; McGinnis and Ostrom, 2014) and associated rationales.

The second question is explored in Phase 2, based on interviewing people who work in key roles in the broader QFly management innovation system, including representatives from three levels of government, peak industry bodies, researchers, consultants and regional coordinators. A grower survey also sheds light on both research questions. The research methodology and methods are explained in greater detail in Chapter 2.

The key contribution that this work makes is to deepen understanding about the social and institutional aspects of industry-driven fruit fly AWM as this area remains underexplored. Other academic contributions are discussed in Chapter 5, such as to socio-ecological systems thinking, including the commons and adaptive co-management. There are also

contributions to community engagement about pest management and the agricultural innovation systems rationale in the context of plant biosecurity.

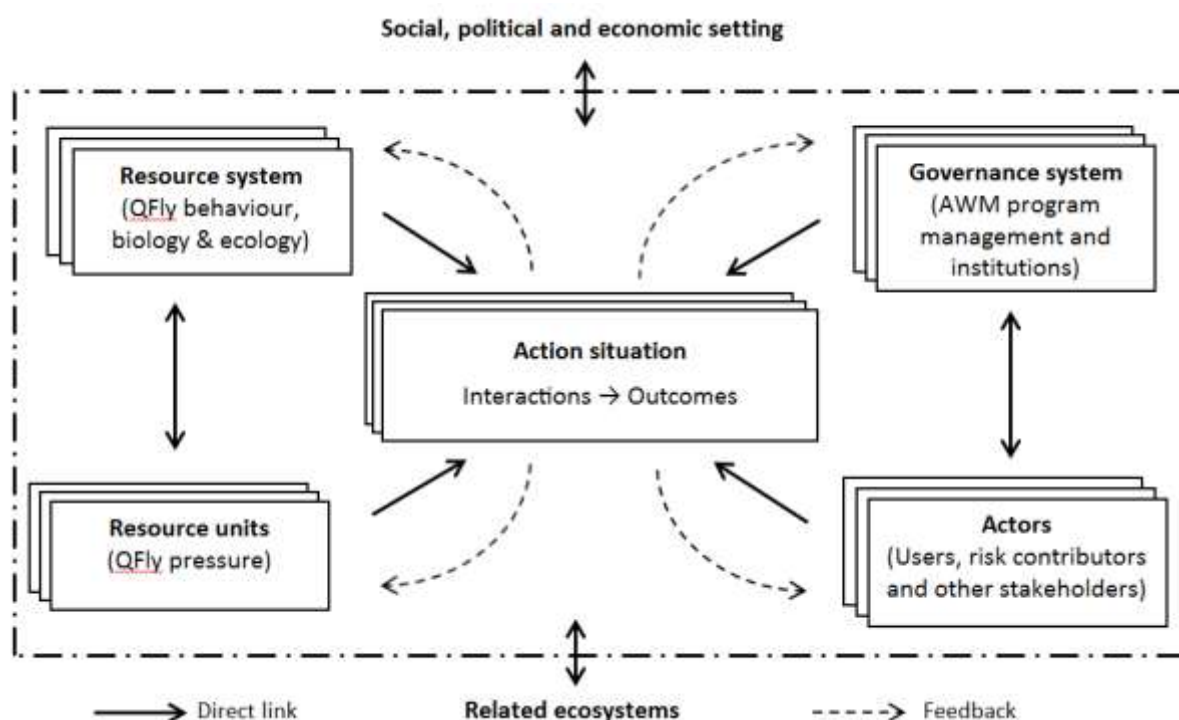
#### **1.4 AWM as an action situation**

The conceptual foundation for this study from which the journal articles flow, is that AWM is an ‘action situation’ as proposed by Ostrom (1990). This is depicted in the socio-ecological systems framework illustrated in Figure 1. The regional level involves interaction between different components:

- Actors – that is, the risk contributors (horticulture growers and other rural landholders who contribute to QFly risk) and others who can influence the success of an AWM program, such as local AWM management groups members, crop consultants, researchers, market access experts, community groups and other relevant staff in government bodies, grower associations, research and development corporations and peak industry bodies.
- A governance system – that is, the local formal and informal institutions that outline how the program and its management operate.
- The natural resource – that is, no or low QFly prevalence. Key natural factors that impact on QFly prevalence include the pest’s natural behaviour, biology and ecology.

Each component can be sub-divided into multiple variables. Several of these could be sub-divided yet again in different variables, as illustrated by the stacked text boxes. These components are also embedded in and impacted by broader systems that can either hinder or enable local initiatives. These include broader ecosystem processes, such as climate change, and the social, economic and political context that sets conditions for the local governance system and the decision-making of actors. For example, the local AWM

governance system is embedded amongst others in the broader national and international plant biosecurity governance system.



**Figure 1. Applying the socio-ecological systems framework as a lens for QFly AWM (adapted from McGinnis and Ostrom, 2014)**

Traditionally, improving on-ground pest and disease management—like other agricultural on-farm practices—has been conceptualised as in need of transferring expert knowledge, such as from relevant scientists, to farmers. Increasingly social scientists call for better integration of different knowledge systems, such as scientific expertise, local knowledge and other, to achieve on-ground progress (Klerkx et al., 2012b; Enticott and Wilkinson, 2013; Reed and Curzon, 2015). This is in part to be cognizant of and work with factors that influence stakeholder support—including on-ground behaviour change and adoption of new practices—and that stretch beyond the transfer of scientific facts. These factors include things such as the norms, values, risk perception, attitudes, motivations, goals, capabilities, capacities and the resource availability of different stakeholders. In addition, modern approaches to achieving on-ground progress in agriculture emphasise systemic thinking. Besides technological advances, this also includes a focus on the multitude of

interactions between players and the institutional context across levels (Klerkx et al., 2012b; Schut et al., 2014). As biosecurity at its core is about risk management, increasingly social scientists push for greater acknowledgement of the biophysical, social and institutional uncertainties involved in biosecurity management and how it is being approached (Reed and Curzon, 2015; Cook et al., 2010).

The key arguments that this thesis postulates include that the social and institutional aspects of industry-driven AWM influence the transaction costs of achieving industry-driven AWM and therefore have a major bearing on the feasibility of such programs. For example, the local social profile influences the effort needed to introduce and maintain local institutions for AWM, including achieving cooperation from risk contributors and gaining support from other stakeholders. It also relates to the effort and cost required from local industries in order to secure the needed support in the form of knowledge, capabilities and resources. Such transaction costs are easily overlooked when benefit-cost analysis of AWM programs is carried out.

In reference to Figure 1, this study focuses on the actors, governance system, the action situation at the local level, as well as how an enabling institutional environment can be created to support industry-driven AWM. These aspects will be explored throughout the subsequent chapters as they encapsulate the social and institutional aspects of industry-driven AWM. The rest of Chapter 1 will provide the context of this work by describing the remaining components presented in Figure 1, that is, the current resource system, including QFly behaviour, biology and ecology and how these factors impact on QFly pressure. This is followed by an overview of the current social, political and economic settings and the current broader QFly management governance system.

### **1.4.1 The influence of QFly behaviour, biology & ecology on QFly pressure**

QFly was once considered native to the tropical and subtropical forests and mangroves of Queensland and northern New South Wales only (Dominiak and Ekman, 2013; Gilchrist et al., 2006). Nowadays it is more widely established throughout parts of eastern Australia and has invaded some South Pacific islands (Clarke et al., 2011). Three key factors influence the survival and reproduction of QFly in any region, these comprising temperature, moisture (Bateman, 1972; Dominiak et al., 2006) and the availability of hosts (Clarke et al., 2011; Muthuthantri, 2013). Significant differences in QFly susceptibility exist between hosts depending on the season, fruit maturity, the physical characteristics of the host plant (such as whether the fruit's skin and flesh is suitable to support QFly activity), and the nature of the host plant foliage for shelter (Lloyd, 2007).

Throughout the warmer months, the female lays her eggs in maturing and ripe fruit. Hatching maggots and other related decay can cause extensive crop losses (Clarke et al., 2011). Female adults live for several months and each can lay hundreds of eggs in her lifetime (O'Loughlin et al., 1984). Hence such conditions can generate five overlapping generations or more per year, causing large populations in late summer and autumn (Dominiak, 2007). As climate affects the time a generation takes to mature, there are significant differences between regions in terms of how growers are affected by the pest, such as between temperate and tropical areas (Muthuthantri, 2013). Humidity as a result of irrigation can also make a region more favourable to QFly (Ha et al., 2010).

Extreme high or low temperature can significantly reduce and even temporarily eliminate fruit fly populations in a region (Lloyd, 2007). Fruit fly becomes less active during winter (Dominiak and Ekman, 2013; Yonow and Sutherst, 1998), and in some areas fruit fly pressure in spring is related to whether the region had a cold or mild winter. It is, therefore, not uncommon to find significant variation in fruit fly pressures between seasons and consecutive years, due to natural conditions (Florec et al., 2013).

Recent years involved wet warm seasons in eastern Australia resulting in expanded QFly populations in several regions (Dominiak and Ekman, 2013). The vulnerability of horticulture industries to QFly in Australia's southern states is forecasted to increase significantly due to the predicted temperature rise resulting from climate change (Sutherst et al., 2000).

The distances across which QFly travels are critical to explaining why AWM is a potentially useful tool, but also why the non-farm community's involvement is essential. Several studies show that an individual QFly travels a few hundred metres to a few kilometres in a lifetime (Clarke et al., 2011; Meats and Edgerton, 2008; Dominiak and Ekman, 2013).

Distances as far as 94 km per fly have also been recorded (MacFarlane et al., 1987), but this is regarded as highly uncommon (Dominiak et al., 2003). Yet, Clarke et al. (2011) calls for finding resolution about QFly's true flight distance. Even if flight distances are limited to a few hundred metres, this is still of considerable concern in regions where orchards are adjacent to towns, such as in Mundubbera (Central Burnett, Queensland) and Leeton (the Riverina, New South Wales) (Figure 2).



**Figure 2. Orchards adjacent to town areas in Mundubbera (left) and Leeton (right)**

### **1.4.2 The social and political context of plant biosecurity**

Pests have been a challenge to humankind since time immemorial. Globalisation, modernisation and a range of concurrent paradigms and discourses have shaped how the



issue is framed and dealt with (Hinchliffe and Bingham, 2008). This section provides an overview of the international and national paradigms and developments that influence the way pests, including QFly, are perceived and approached in the agriculture policy space. In other words, it uncovers the underlying and often hidden assumptions about social and political connections that shape and influence policies, including who is included and who might be marginalised or excluded (Keevers et al., 2008). Macro-level discourses involve a set of interrelated thoughts, expressions and practices that are embedded in history (Foucault, 2002). Discourse shapes how certain issues are discussed or suppressed, as well as when and by whom. Hence it determines which interventions are promoted or restrained and what changes will be introduced (Keevers et al., 2008). For example, the rebranding of the centuries-old practice of addressing agricultural pest and disease issues as biosecurity is noteworthy as it demonstrates how current societal concerns about globalisation influence agriculture in new ways (Waage and Mumford, 2008). Biosecurity brings 'life' into society's political realms, including favouring certain forms of life over others (Braun, 2013). Paradigms and discourse shape the roles and responsibilities of the state, industry and the broader community. Most fundamentally, biosecurity represents a social and institutional construct that is historical rather than universal in nature (Braun, 2013). This involves multiple ways of safeguarding agricultural space from pests and diseases (Hinchliffe, 2007). Outlining the social and political dimensions of biosecurity is not to dismiss current biosecurity efforts, but to understand what underpins current approaches and rationales (Braun, 2013).

### ***Neoliberalism and trade liberalisation***

Globalisation brought with it neoliberal thinking, a loose assemblage of ideas that resulted in increased market rule approaches in modern societies (Maye et al., 2012). Key themes of neoliberalism include a shrinking role for the state in society, an increase of the role of markets and consequently deregulation. During the 1980s, Australia became a supporter of

international discourses around neoliberalism (Dibden et al., 2011; Halpin and Guilfoyle, 2004; Gill, 2011; Measham et al., 2012). Australia is a strong advocate of a 'level playing field' in the international trade arena (The Cairns Group, 2013) underpinned by trade liberalisation and the minimisation of domestic agricultural support. This in part results from Australia being a highly export-focused country, which seeks to increase its competitiveness against international opponents, where farmers are protected and/or subsidised (Dibden et al., 2011). Indeed, agricultural policy scholars universally describe Australia as deploying a neoliberal policy paradigm (see for example Coleman, 2001; Pritchard, 2005; Gray and Lawrence, 2001; Alston, 2004; Higgins et al., 2016).

Similarly, the World Trade Organisation (WTO) and the International Plant Protection Convention (IPPC), promote free trade while using a science-based approach in a bid to minimise biosecurity risk. The Agreement on the Application of Sanitary and Phytosanitary Measures (the 'SPS Agreement') provides the principal rules for maintaining animal and plant health during international trade (WTO, 1998). Government agencies in member countries need to fulfil a range of roles and responsibilities under WTO arrangements, including conducting import risk assessments to distinguish genuine biosecurity measures from unwarranted justification for trade protection (Alam and Rolfe, 2006; Dibden et al., 2011). For example, the IPPC develops International Standards for Phytosanitary Measures (ISPMs) that allow for assurances that pest risks are addressed. The first systems approach-related ISPM, ISPM 14, appeared in 2002 followed by ISPM 35 in 2012 specifically for fruit flies. Other relevant standards include for areas of low pest prevalence (ALPP) (ISPM 29 and 30) and for fruit fly pest-free areas (ISPM 26 and 29), both commonly supported by an AWM approach. There are also nationally agreed principles and procedures to manage surveillance, trapping, outbreaks and eradication from fruit fly pest free areas.

In other words, these processes attempt to render biosecurity and increased international trade as compatible aims (Maye et al., 2012) by harmonising biosecurity practices between

countries (Dibden et al., 2011; IPPC, 2006). Hence, agriculture-related policies and activities, including in relation to AWM, are increasingly aligned with international market logics (Maye et al., 2012; Outhwaite, 2013) and less so on local needs and priorities (Wissemann et al., 2003; Outhwaite, 2013).

Trade liberalisation and biosecurity are contested spaces, as the adequacy of science-based and regulatory approaches to manage biosecurity is increasingly critiqued (Maye et al., 2012; Dibden et al., 2011; Outhwaite, 2010). Politics influence trade-related decisions and the framing of scientific information (Simberloff, 2005; Dibden et al., 2011; Maye et al., 2012; Potter, 2013), for example, during import risk assessments (Potter, 2013; Higgins and Dibden, 2011). Governments are often torn between trade obligations, domestic agricultural industry demands and consumers' wishes for cheaper food. The long list of WTO SPS disputes suggests that governments still use SPS measures as de facto trade barriers to protect their own industries (Trampusch, 2014).

### *The 'risk society' and categorisation*

Biosecurity management presents a prime example of the 'risk society', which involves modern society increasingly being concerned about assessing and controlling risks to personal safety, health and the environment and who is responsible for addressing these issues. It means society organises itself around the distribution of 'bads' rather than 'goods' (Beck, 1992; Giddens, 1999). In the context of QFly management this involves greater scrutiny of pesticide safety and finding systematic, science-based ways to deal with the risk of pest spread through trade.

Hence, there is a presumption that processes of categorisation, ordering and accompanying rules can stem the flow of unwanted organisms from 'unclean' infested areas to 'clean(er)' controlled areas and provide assurances that produce is free of unwanted organisms. In particular, control of human behaviour is seen as the key mechanism to achieve desired

outcomes (Donaldson and Wood, 2004) in a realm that in practice involves a complex interplay between the environment, host plants, humans and the problematic organism, here QFly.

### *The positivist approach*

A consequence of the WTO's and IPPC's activities, the SPS Agreement and the focus on science-based evidence is that biosecurity is generally approached as a 'technocratic discourse' by governments and agriculture industries (Dibden et al., 2011; Potter, 2013). This involves a positivist mode of thinking based on objective and absolute knowledge. Schut et al. (2014) conducted a meta-analysis of crop protection literature and concluded that the great majority of publications are technology-oriented with the institutional and political dimensions of crop protection seldom addressed. Enticott and Wilkinson (2013) point out that biosecurity is characterised by the formation of 'knowledge hierarchies' dominated by a rational, natural science perspective. It follows that biosecurity policy tends to assume spatial homogeneity (Larsen, 2009). However, as implied in the earlier discussions about fruit fly AWM and QFly management, in reality biosecurity responses involve a complex interaction of the geospatial, behavioural and biological sciences (Enticott and Wilkinson, 2013). Hence, some argue for a shift in thinking from 'breach points' based on reductionist thinking towards thinking around 'tipping points' caused by the interaction of different conditions that together could cause 'bio-insecurities' (Hinchliffe et al., 2013).

### *New Public Management and rural restructuring*

The support for neoliberal approaches is also informed by New Public Management, an approach that supposes that market-oriented management of the public sector leads to a more efficient government (Hood, 1991; Johnston, 2000). This includes a shift in government approaches from public service to service delivery, involving privatisation of traditional government services, corporatisation of the way the public service is managed

and an increased emphasis on public-private partnerships (Gahan, 2007; Connell et al., 2009).

These rationales resulted in an on-going systematic restructuring of rural Australia (Cheshire and Lawrence, 2005; Dibden et al., 2009; Martin and Ritchie, 1999), where governments took on the role of facilitator of progress and development rather than direct actor in agriculture, as with other economic sectors (Rose, 2000; Gill, 2011; Wissemann et al., 2003). The rural policy direction of governments in Australia, at both federal and state levels, has shifted to service rationalisation to achieve economic efficiency (Gerritsen, 2000b), involving progressive cut-backs of the extensive farmer support of previous decades (Bjørkhaug and Richards, 2008) and employing strategies favouring self-reliance (Cheshire and Lawrence, 2005). This approach was supported by farmers' lobbies, like the National Farmers' Federation, so that Australia and New Zealand were alone among OECD nations in reducing agricultural support mechanisms (Gerritsen, 2000a). The philosophy is to bring farmers closer to international market signals to deliver efficient commodity production where market forces play a key role in shaping rural development (Measham et al., 2012; Martin and Ritchie, 1999). Australian farmers are now some of the least government-supported farmers in the world (OECD, 2013; Gerritsen, 2000a). Ironically, in the context of AWM—which requires collective action—some term it the 'individualisation' of risk, whereby the responsibility for managing the risks of modern life has been redistributed from the government and the economy to the individual (Cheshire and Lawrence, 2005).

### *Shared responsibility and partnerships*

The increased emphasis on public-private partnerships has left its mark on biosecurity policy. During 2008 an independent investigation of Australia's biosecurity system, the Beale Review, titled 'One Biosecurity: a working partnership' (Beale et al., 2008), was released. This followed the Nairn Report, titled 'Australian quarantine – a shared

responsibility' (Nairn et al., 1996). The concepts of biosecurity as a partnership and a shared responsibility between government, industry and the community are now key themes in key strategic biosecurity documents of both the Australian Government and the state and territory governments. This includes the recent National Fruit Fly Research, Development and Extension Plan (Plant Biosecurity CRC, 2015). The shared responsibility beyond industry is justified with the notion that the broader Australian community derive benefits from sound biosecurity, including better food security and quality, stronger trade and greater environmental preservation (Fraser, 2016).

However, the concept of partnership and the appropriate roles and responsibilities of different partners are contested. The nature of the bond between government and citizen can be understood differently by each party. Responsibilities attributed by the state to the other two parties does not guarantee that they accept and enact these (Gill, 2011). A lack of clearly defined roles and responsibilities, transparency and good communication results in ambiguity and tension (Higgins et al., 2016). Some question whether the broader community is a true partner, as it has limited opportunity to shape the biosecurity agenda (Barker, 2010). Donaldson (2013) posits that in this context the community's biosecurity responsibilities become an extension of government and agriculture industries' biosecurity apparatus, often for trade-related aims.

Enticott and Franklin (2009) argue that government remains the most powerful partner in the partnership systems, as it has superior expertise and it is able to give effect to its ambitions through a range of mechanisms such as programs, policies, documents and procedures. Hence, the state has unique resources and abilities, including legislative powers, democratic legitimacy, staff and budgets (Carlsson and Sandström, 2007).

From industry's perspective, the biosecurity roles and responsibilities of government stemming from international and national institutions make government a QFly

management partner with many faces. For example, the ‘faces’ of state governments include:

- regulators that increasingly shape policies to mirror international plant biosecurity and market access rules set by the WTO and IPPC
- implementers of national and international trade rules such as those contained in trade protocols, including doing auditing of policies and procedures, issuing accreditation certifications, and inspecting fruit destined for certain markets
- negotiator for market access to other domestic states and territories
- funder and in-kind contributor to QFly-related activities, including research and other support activities
- local partner in achieving AWM for a range of regions, including advising on how to apply in-field QFly control to maximise chances to gain market access and win extended support from government.

The first three roles are similar for the Australian Government in assisting Australian growers to gain access to international markets. This illustrates the unique relationship, but also the power differential that exists between horticulture industries and government agencies at all levels.

Clearly defining the roles and responsibilities of the different partners is further challenged by determining how to best invest scarce resources for biosecurity, as the sources and potential impacts of biosecurity risks are multiple (Craik et al., 2016; Donaldson, 2013). Agricultural biosecurity is now part of a broader biosecurity agenda that also includes addressing environmental biosecurity concerns. More diverse biosecurity threats increasingly come to the fore, requiring agricultural biosecurity resources to be increasingly

thinly spread (Waage et al., 2005). For example, the increased push for expanded tropical horticulture in northern parts of Australia will require more investment in understanding Australia's endemic tropical fruit flies (Plant Biosecurity CRC, 2015). Trade-offs are needed between pre-border, border and post-border protection, and between reducing impacts on agriculture trade and production, the environment and social amenity (Cook et al., 2011). Investment prioritising is further needed between prevention, eradication, containment and asset protection (Fraser et al., 2006; Waage and Mumford, 2008). A key principle underpinning contemporary biosecurity spending is maximum return on investment (Cook et al., 2010; Beale et al., 2008).

### *Agriculture's loss of hegemony*

Agriculture has lost its hegemony in rural areas during the last few decades as new groups and interests have gained prominence (Dibden et al., 2009; Bjørkhaug and Richards, 2008). Many rural areas have seen a growing diversity amongst rural actors (Groth et al., 2014) and hence competition between them. This implies that policy-makers have to deal with more social, economic (Enticott and Franklin, 2009) and environmental pressures (Argent, 2002). Some Australian rural areas have experienced an influx of people involved in mining, tourism and agriculture value-adding industries (Wissemann et al., 2003; Miller et al., 2012). This means growers can no longer expect that their interests, such as a wishing for drastic action to manage QFly, will be prioritised over those of other groups inhabiting the rural space.

### **1.4.3 The economic context of Australian horticulture**

During the 1980s and 1990s Australia witnessed strong agricultural productivity growth, which has been largely attributed to extensive neoliberal microeconomic reform that provided greater incentives for innovation and improved performance. The microeconomic reform strategies included opening the economy to competition, trade and investment and the deregulation of industries and institutions (Nossal and Gooday, 2009).



They contributed to significant growth in the production value of Australian horticulture. For example, the production value for fruit rose between 1982 and 2012 from AUS\$632.1 million to AUS\$3506.2 million and for vegetables from AUS\$556.9 million to AUS\$3417.5 million per year (ABARES, 2012).

However, there is also evidence that hard-line neoliberal approaches have caused considerable hardship in rural Australia. Whereas most of Australia's metropolitan areas have benefited from neoliberal approaches over the last few decades, many areas in rural Australia have experienced negative trends, such as a loss of farmers, depopulation, increased unemployment, ageing population and withdrawal of services and private investments (Cheshire and Lawrence, 2005; Dibden et al., 2009; Vanclay, 2003; Alston, 2004). Many Australian farmers are struggling to maintain viability (Halpin and Guilfoyle, 2004) or, at least, becoming increasingly vulnerable (Dibden et al., 2009). For example, the Productivity Commission (2002), in reference to unpublished ABS data, indicates that in 1993–1994 there were well over 3,500 citrus establishments in Australia, whereas by June 2015, this figure was 1,120 (ABS, 2016a). In short, there are many fewer farms than in the past, but there has been a shift to larger farms. Most output is delivered by a small proportion of farms, involving large commercial operations (Productivity Commission, 2005).

The two main industries covered in this work are the citrus and cherry industries. The citrus industry, the largest exporter of fresh produce in Australian horticulture, had a local value of AUS\$411 million during 2014–2015 (ABS, 2016b), an increase from the equivalent value in 2000–2001 of AUS\$309 million (ABS, 2003). During the 2000s it experienced several challenging years involving drought, wet summers and a record high Australian dollar. The industry's fortunes turned around in 2012–2013 with increased export demand and stronger prices (Citrus Australia, 2013). The 2014–2015 season brought high export demand and a better growing season, resulting in a ten year record citrus export value

(Citrus Australia, 2015) estimated in the order of AUS\$275 million for the 2015 calendar year (Fresh Intelligence Consulting, 2016). These exports involve a total of almost 200,000 tonnes of citrus, comprising almost 150,000 tonnes of oranges and almost 50,000 tonnes of mandarins (ibid.). The Senate Standing Committee on Rural and Regional Affairs and Transport undertook a review of the citrus industry in 2013. Key challenges identified for the Australian citrus industry included high production costs related to high electricity, water, regulation and labour costs, while the industry faced direct competition with lower-cost offshore producers, such as from South Africa, Chile and Peru. Phytosanitary concerns, of which QFly is a key one, are a major barrier to expanding exports to protocol countries. The export protocols that growers are required to comply with can be onerous, expensive, and time-consuming to meet. Growers also face competition from imported cheap fruit juice concentrate (SSCRRAT, 2013).

The cherry industry has also undergone remarkable growth since the early 2000s. The local value of the Australian cherry industry was AUS\$ 55.5 million in 2001 (ABS, 2003) and rose to over AUS\$133.7 million during 2014–2015 (ABS, 2016b). The industry reached an export record 5,600 tonnes during the favourable 2015–16 season, valued at around AUS\$77 million (CGA, 2016). Australian cherries are exported to over 30 countries (ibid.). There is opportunity to further grow exports as more growers show interest in supplying overseas countries and most current export markets show growth in their cherry imports. Over the last decade the Australian cherry industry, or parts thereof, was plagued by a strong Australian dollar for most of the period from 2008 to 2014. In some cases non-protocol countries became protocol countries, such as Thailand, which caused a temporary loss of this market. Further challenges for market expansion include high production costs; growers lacking export ‘readiness’ including a lack of export knowledge, limited pest free areas and strong competitors in the southern hemisphere, in particular Chile and New Zealand (CGA & HAL, no date). Tasmania and the Riverland in South Australia are

recognised internationally as pest free areas (CGA & HAL, no date) and they therefore enjoy better export conditions than the other mainland cherry growing regions.

In terms of future economic conditions, a range of new bi- and multi-lateral agreements that were signed during the last three years promise better trade opportunities for Australian horticulture. These include the Trans Pacific Partnership Agreement (HIA, 2016) and free trade agreements with Korea, Japan and China (Hyde, 2015). It is foreseen that the free trade agreements will reduce or eliminate import tariffs on several Australian agricultural exports to these countries over the coming 20 years. For example, as part of the China FTA, all tariffs on horticulture, including tariffs of up to 30 per cent on citrus, will be removed over eight years. As part of the FTA with Japan, the 24 per cent tariff on cherries was eliminated when the agreement commenced on 15 January 2015 (ibid.). However, QFly as a technical barrier that either prevents market access or requires costly phytosanitary measures, remains a key concern to horticultural industry stakeholders (Metcalf, 2015). It must therefore be addressed for the full benefit of these arrangements and for increased exports to be realised.

#### **1.4.4 QFly management governance context**

This section provides an overview of the key regulatory activities and instruments across the international, national and state and territory levels.

##### ***Trade requirements***

In the international trade context, the IPPC develops International Standards for Phytosanitary Measures (ISPMs) that allows for assurance that imports are not the source of pests. According to WTO policies, compliance with ISPMs are consistent with the SPS Agreement (WTO, 1998). A number of ISPMs are relevant to fruit fly AWM as AWM underpins phytosanitary measures such as PFAs and ALPPs. The most relevant ISPMs are:

- ISPM 04 – Requirements for the establishment of pest free areas

- ISPM 14 – The use of integrated measures in a systems approach for pest risk management
- ISPM 22 – Requirements for the establishment of areas of low pest prevalence
- ISPM 26 – Establishment of pest free areas for fruit flies (Tephritidae)
- ISPM 29 – Recognition of pest free areas and areas of low pest prevalence
- ISPM 30 – Establishment of areas of low pest prevalence for fruit flies (Tephritidae)
- ISPM 35 – Systems approach for pest risk management of fruit flies (Tephritidae)
- ISPM 37 – Determination of host status of fruit to fruit flies (Tephritidae)

Australian horticulture industries wishing to pursue technical international market access, such as with strict phytosanitary conditions, need to submit their applications to a specially-appointed industry panel. The application typically requires the inclusion of rigorous data as evidence in support of the proposed market entry; hence such applications are often preceded by a thorough research and development process. The panel considers the proposals and is responsible for assisting Horticulture Innovation Australia to provide advice to the Department of Agriculture and Water Resources (DAWR) about the prioritisation of horticulture market access applications. DAWR is responsible for international market access protocol negotiations. Until mid-2015, this panel was the Office of Horticulture Market Access. It has been replaced by the Trade Assessment Panel, which is supported by an Industry Advisory Panel (HIA, 2015). Technical international market access application processes are often long and arduous and it can take many years before access is granted.

Application for domestic market access follows a different process. The Subcommittee on Domestic Quarantine and Market Access oversees the development of domestic market

access conditions for horticulture to ensure they are technically justified with minimal regulatory burdens on industry; harmonised and coordinated as far as possible; and aligned with international import and export market access conditions and policies (SDQMA, 2016). Increasingly domestic trade is modelled on international trade arrangements as an exemplar. Over time successful domestic protocols then strengthen evidence to support international market access applications using the same protocol (NFFS Implementation Committee, 2009).

Most pertinent to domestic market access is the interstate certification assurance (ICA) scheme, which governs the movement of horticultural produce throughout Australia (Jessup et al., 2007). This scheme involves various protocols to provide assurances to importing states that certain pest risks have been addressed following verifiable standard operating procedures, many relating to QFly.

Australia's QFly management Code of Practice is a key guidance document outlining rules recognised by domestic and some international markets as the basis for controlling QFly and developing international market access opportunities. The current Code (1996) is regarded as outdated partly because it does not make allowance for more recent measures such as maintaining areas of low pest prevalence. The Code contains detailed prescriptions, including the type of QFly monitoring traps required, their spacing specifications in the context of pest free areas and thresholds for the number of flies caught per trap before corrective action is required (IPHRWG, 1996).

#### *Other aspects of Australian fruit fly management coordination and regulation*

Australian plant biosecurity involves a multitude of committees, sub-committees, working groups, agreements, legislation and regulations, many of which impact to a greater or lesser extent on QFly management. However, a full overview of Australia's plant biosecurity

system falls outside the scope of this document and only key components are summarised here.

Australia has a centralised approach to biosecurity governance (Cook et al., 2010). Within Australia, plant biosecurity management is controlled through Commonwealth and state legislation, administered through a range of government departments across all jurisdictions responsible for agricultural and environmental issues (PHA, 2012). The Australian Government, in particular DAWR, is mainly responsible for post-border (offshore) and border biosecurity issues (Cook et al., 2010; Beale et al., 2008). DAWR plays a limited role in establishing and managing regional QFly management initiatives. However, it is responsible for fulfilling international phytosanitary obligations, such as certifying produce for compliance with international phytosanitary measures. It also plays an important role in international trade negotiations (PHA, 2012). Key legislation at the national level is contained in the *Biosecurity Act 2015* which replaced the *Quarantine Act 1908* on 16 June 2016.

On the domestic front, state government departments responsible for agriculture oversee post-border (onshore) plant biosecurity, in collaboration with plant industries (PHA, 2012). Each state and territory has its own plant biosecurity-related legislation and several have current biosecurity strategies. They have different approaches to delivering plant biosecurity operations due to reasons such as geography, climate, differences in population density, ability to fund biosecurity activities, the volume of interstate trade and the importance of agriculture to the state's economy (Cook et al., 2010). Some states, such as Victoria, have developed their own fruit fly management plan, i.e. *Managing fruit fly in Victoria – Action Plan 2015–2020*.

Plant Health Australia (PHA) facilitates the government-industry plant health partnership in Australia. It collaborates with representatives from federal and state governments and

industry to improve policy, practice and performance of Australia's plant biosecurity system. It is a not-for-profit company funded by Australian government, state and territory governments and industry levies (PHA, 2012). It provides secretariat and executive support to the National Fruit Fly Council (NFFC) (PHA, 2017).

The Australian Government, state and territory governments, plant industries and the research community collaborated to develop the Draft National Fruit Fly Strategy (NFFS) released in March 2008. It contains 20 recommendations and 80 strategies across key operational, policy and research areas. This was followed by the National Fruit Fly Strategy Implementation Action Plan, released in April 2010, which involves 15 key initiatives and projects to implement the key recommendations contained in the draft NFFS. The NFFS Implementation Action Plan is designed to, amongst other things, enhance domestic and international market access, improve coordination and reduce any overlap of effort and duplication of resources and provide support for local industry management of fruit flies. It identifies AWM, ALPP and PFAs as *'critical areas in which investment is required'* (NFFS Implementation Committee, 2009: p23). The economic benefit of a national approach to control fruit fly (QFly and MedFly) through the implementation of NFFS is estimated between \$29 and \$38 million per year (Abdalla et al., 2012).

Key funders of fruit fly-related research include Horticulture Innovation Australia Limited (HIA), a research and development corporation. HIA administers the industry research and development levies, which the Australian Government matches dollar for dollar under the *Primary Industries Research and Development Act 1989*. Other key research bodies include the Plant Biosecurity Cooperative Research Centre (PBCRC), universities, Commonwealth Scientific and Industrial Research Organisation, Australian Bureau of Agricultural and Resource Economics and Sciences, and state government departments. A range of collaborations exists.

A number of significant developments have occurred since the research reported here was initiated in 2013:

- The PBCRC released the National Fruit Fly Research, Development and Extension Plan in 2015 (Plant Biosecurity CRC, 2015). This was followed by a consultation process involving seven stakeholder workshops across Australia (Metcalf, 2015).
- The National Fruit Fly Advisory Committee (NFFAC) was launched in May 2014 to provide strategic direction to fruit fly policy and RD&E in Australia. The NFFAC morphed into the NFFC at the end of 2015, a government and industry committee. Its role is to provide national leadership and coordination to manage fruit fly in Australia, including implementing the NFFS Implementation Action Plan and working with growers and fruit fly management community groups to control the pest. The Council also involves a full-time National Manager, based in PHA, to progress the Council's plans.
- the establishment of a sterile insect technique consortium called SITplus (HIA, 2015), which besides conducting extensive research involves the development of a SIT rearing facility in Port Augusta, South Australia and the appointment of a SITplus Program Director and a QFly Area-Wide Management Coordinator. These two roles are based in HIA and work closely with the NFFC's National Manager.

## **1.5 Summary**

The discussion above illustrates that AWM of QFly occurs in a complex context resulting from an entangled network amongst interacting 'multiples' (Poteete, 2012; Hinchliffe et al., 2013). There are multiple crops, geographical and climatic conditions, types of enterprises and on-farm objectives. Commodity groups differ in how well they are organised. Many stakeholder groups are involved, including the three levels of government, different groups



within government departments, various public and private research providers, consultancy services and multiple horticulture industries. Markets are embedded in global institutions through the WTO's trade rules; domestically there are a myriad of laws, regulations and expectations that shape the rules by which AWM programs need to abide.

It is also a context that has seen considerable change in recent decades. A range of trends have reshaped connectedness and scale, including the relationship between markets and governance, leading to new forms of interdependencies and geopolitical power. The increasing interconnection, such as between markets and producers across the globe, leads to greater uncertainty and blurs the benefits and costs of policy options (Young et al., 2006). Decisions at one place have a significant influence on decision-making and action in another place (Folke et al., 2005). More recently, a range of new initiatives, pesticide regulations and governing structures in the fruit fly arena are changing how the issue of QFly is being approached. Change can also mean that the rules and norms to guide policy formulation are not always well-defined. This can cause challenges to and uncertainty over the rules and logic of policy-making and the role of expertise in producing new spaces for biosecurity issues. It raises questions about who should consider, contribute and implement solutions to biosecurity issues and how they should do this (Enticott and Franklin, 2009). As for growers, unlike in the decades following World War II, they can now expect less direct government support, more demanding markets and pesticide regulations and a loss of hegemony in rural spaces. It is therefore imperative that new recommendations such as industry-driven AWM are well understood, not only from a technical but also a social and institutional point of view in order to design an institutional context that will 'help local industries help themselves'. Only then can these ventures be more widely achievable.



## **Chapter 2. Theoretical foundation and research approach**

### **2.1 Introduction**

This study adopts a mixed-methods approach, involving qualitative and quantitative research. This approach was chosen as it bolsters accuracy, delivering a more complete picture as the different approaches complement each other's strengths and weaknesses (Denscombe, 2014). As explained in Chapter 1, there are two key research questions, which are explored across two research phases:

1. What social and institutional factors influence the success of industry-driven AWM at the local level and how can success be maximised? (Phase 1)
2. What are the main constraints to an enabling environment for industry-driven AWM implementation and how can these be mitigated? (Phase 2)

This PhD is delivered by publication, involving four manuscripts that have been accepted and published by academic journals. The fifth article's feedback from the journal's reviewers has been incorporated and the revised article has been resubmitted to the journal. Box 1 (Chapter 1) provides an overview of the journal articles.

The rest of this chapter proceeds as follows: In the next two sections the theoretical underpinnings of Phase 1 and Phase 2 are briefly introduced. This chapter concludes with a discussion about the methods used across both research phases.

### **2.2 The theoretical underpinnings of Phase 1**

Phase 1 investigates how the chances of establishing successful fruit fly AWM can be maximised at the local level. It involves an inductive-deductive interplay between using and

developing theory (McGhee et al., 2007; Eisenhardt and Graebner, 2007) using three case studies as empirical evidence and integrating findings from that interplay with relevant literature. It applies an interpretivist theoretical perspective (Denzin and Lincoln, 2000) to understand the real-life situations of growers and key stakeholders located in the case studies.

Eisenhardt and Graebner (2007) stress that it is important to justify why research questions are better addressed by theory-building instead of theory-testing research, that is, by showing that there is a lack of plausible existing theory. Knowledge about the social and institutional aspects of fruit fly AWM is scant as traditionally issues related to fruit fly and AWM are addressed from a predominantly technical point of view (see the discussion on the positivist approach on p34). Plant biosecurity issues such as fruit fly also have unique aspects that are less common in other reported socio-ecological systems, including the linkage to market access, which implies that fruit fly AWM programs are nested in a highly regulated and contested broader institutional context. In addition, fruit fly AWM typically involves a large range of risk contributors whose support is vital to the success of the undertaking, but who may have little direct incentive to participate. A lack of public support is one of the biggest challenges of industry-driven AWM (Mumford, 2000). Hence, existing theory, such as those dealing with socio-ecological systems, falls short of fully encompassing the challenges faced by fruit fly AWM programs. However, the work reported here is underpinned by the belief that existing theory can make a significant contribution to understanding and strengthening fruit fly AWM programs. It draws on a range of complementary theoretical underpinnings, which are described below.

### **2.2.1 Socio-ecological systems**

Phase 1 of this research uses the work pioneered by Elinor Ostrom and others about self-governing socio-ecological systems (SESS) to deepen understanding about how to strengthen industry-driven AWM programs. A SES is defined as '*a structure composed of a*

*common-pool resource [in this case no or low QFly prevalence], its users and an associated governance system'* (Janssen and Anderies, 2007: p44).

In particular, this work uses aspects of the SESs Framework that is often applied to deepen understanding about the sustainable management of natural resources. The conceptual basis of this thesis is the first tier of the multi-tier SESs Framework, as represented in Figure 1 (see Chapter 1). It provides a broad frame for incorporating the interactions between the resource system, resource units, local AWM governance system and actors situated in a certain social, institutional and economic context, which together deliver certain outcomes (Binder et al., 2013; Poteete et al., 2010; Ostrom, 2007).

The SESs Framework was chosen as it acknowledges that humans make conscious choices, both individually and as members of cooperative groups, and that these choices influence outcomes (McGinnis and Ostrom, 2014). The social and governance structures influence how actors behave and shape outcomes through different interactions and feedback loops and with the resource and its related ecology (Binder et al., 2013). The SESs Framework also recognises that local natural resource management (NRM) initiatives are nested in different hierarchical levels of governance systems and that interactions occur between them (Binder et al., 2013; Poteete et al., 2010; Ostrom, 2007; Armitage, 2007; Ostrom, 2005). This includes the need for higher hierarchical levels of the governance system to be responsive to the needs at local levels in order to support them without over-riding local autonomy (Ostrom, 2005; Marshall, 2005).

Translated into the context of fruit fly AWM, this means that local institutions encapsulate the strategies and activities employed at the regional level to control fruit fly. They incorporate ways to ensure cooperation of a critical mass of risk contributors to lower and maintain fruit fly numbers at the desired level. It also includes recommended best practice promoted to growers and other host plant owners, such as town residents; the fruit fly

control activities undertaken by other stakeholders, such as local councils or other government bodies; and stakeholder engagement strategies. The local action situation is nested in the wider political and economic setting of national and international trade in which fruit fly AWM programs are embedded. This will influence the level of QFly management employed and how management activities are executed by different host plant owners.

Some explanations of resource management outcomes require focus on both the micro-situational level as well as the broader level in order to highlight the relationship between the two levels (Poteete et al., 2010; Berkes, 2007). These kinds of issues are conceptualised as ‘complex adaptive systems’. This refers to systems involving multiple autonomous elements, or variables, which continuously interact and shape each other. The patterns of behaviour cannot simply be understood by analysing its individual elements (Marshall, 2005).

The literature review findings about how biosecurity is currently constructed (see 1.4.2) suggest there is a tension with socio-ecological systems thinking. In the market access space, biosecurity institutions of WTO member countries, such as Australia, and their associated jurisdictions are by and large shaped by the international trade logics (Maye et al., 2012; Outhwaite, 2013) rather than on these regions’ own needs and priorities (Outhwaite, 2013). For example, the governments in Australia at both national and state/territory levels to a great extent align their biosecurity policies with international rules and less so on local needs and priorities (Wissemann et al., 2003; Outhwaite, 2013). Some scholars have called for greater adaptive governance including shifts from Australia’s prevailing centralised biosecurity governance system towards more polycentric systems. This is to better deal with the uncertainty, risk and complexity that is so inherent to biosecurity (Cook et al., 2010).

Moreover, Marshall (2005) points out that mainstream economics often assumes optimal institutional design at the start of collaborative environmental management systems. Yet, there is a substantial need for negotiations, renegotiations and coordination throughout the life of these management systems (Dentoni et al., 2012), which involve costs. In the context of industry-driven AWM, local industries also need to find ways to ensure risk contributors continue to comply with QFly management practices. The monitoring and enforcement of this compliance tend to be costly (Poteete and Ostrom, 2004). These kind of costs are known as transaction costs, which can be defined as *'the costs of the resources used to define, establish, maintain, use and change institutions and organisations; and define the problems that these institutions and organisations are intended to solve'* (Marshall, 2013: p188). The cost of achieving policy choice and design, particularly when non-point pollution is involved, can be considerable. However, empirical assessment of NRM policies in this context often do not incorporate such costs (McCann et al., 2005).

Cost benefit analyses of fruit fly AWM in Australia (such as those contained in Ha et al. (2010); Florec et al. (2010) and Chambers and Franco-Dixon (2007)) also show limited reflection of accounting for such transaction costs. Florec et al. (2010) acknowledge the cost involved in education and communication of risk contributors and strategic planning. They also point out that AWM is challenged by the 'weakest link' phenomena, including the issue of individuals' private actions (or lack thereof) that do not take into account the consequences for the social welfare of others. However, there is no acknowledgement that addressing this issue will likely require considerable levels of investment, such as in deliberation with local groups and governments at local and state levels to find workable ways forward. Klassen (2004) points out that considerable cost savings to AWM programs can be expected in areas where there are already processes in place for decision-making, communication and fee collection.

The SESs Framework originates from the political sciences and is based on theories around collective action, common-pool resources and NRM. It applies an anthropocentric perspective of ecological systems, that is, ecological systems are seen as providers of services that support human well-being (Binder et al., 2013). As this framework has most commonly been applied to forests, fisheries, water and pastures (ibid.), this research presents a novel way of applying this framework to commercial pest management. In addition, SESs thinking is seldom applied to issues related to commercial agriculture. Hence this work extends the scope of SESs literature.

### *Common-pool resource theory*

During the 1950s and 1960s there was much pessimism about the potential self-management of common-pool resources. The likes of Gordon (1954) and Hardin (1968) believed that short-term, self-interest of resource users would invariably undermine achieving the high level of benefit to all users if they engaged in voluntary cooperative behaviour. This work led to the belief that common-pool resource preservation is only possible if external authorities impose rules on users (Poteete et al., 2010). Mancur Olson (Olson, 1965) put forward a theory of collective action, by identifying conditions in which self-organising cooperation could emerge. However, this work still had pessimistic undertones, especially in relation to free-riding and the incentive created for users to ‘opt out’ when others do not collaborate in following the rules (Schlager, 2004).

Yet, over time it became clear that many examples exist where people have organised themselves to sustainably manage a common-pool resource. Hence, common-pool resource theory emerged in the 1980s to emphasise the social, institutional and physical factors that influence cooperation between resource users within a region (Agrawal, 2001; Poteete et al., 2010; Villamayor-Tomas et al., 2016). At the core of the evolving common-pool resource theory was Elinor Ostrom’s (1990) design principles for long-term, robust local resource management. She identified eight principles by reviewing numerous case



studies of both successful and failed common-pool resource management systems. The principles were also verified by other scholars (e.g. Cox et al., 2010; Marshall, 2008; Weinstein, 1999) and they are associated with the SESs Framework (Ostrom and Cox, 2010). These principles facilitate the conditions required to sustain the trust and reciprocity that are needed to sustain collective action.

In short, these principles involve the presence of clear resource and social boundaries; congruence between rules and local conditions and equivalence between the cost and benefits of cooperation. Resource users need to have the opportunity to participate in rule-setting and other decision-making that impact on resource management. There is a need for effective and prudent monitoring and sanctioning, low-cost conflict resolution mechanisms and external recognition of the right of resource users to make their own rules. Complementary rule-making and multi-level division of labour are required across scales (Poteete et al., 2010; Cox et al., 2010; Villamayor-Tomas et al., 2016; Ostrom, 1990). These principles were applied to the three case studies and reported in Article 1. The application of the principles in a biosecurity context where a lack of cooperation can contribute to hindering market access opportunities, is novel.

The principles are of great relevance to AWM as success depends on achieving and maintaining collective action between horticulture growers and other landholders with QFly hosts on their land. As Ostrom's principles relate to resource users effectively self-organizing and sustainably managing a commons, they seem of particular relevance in the Australian context with its push for industry-driven AWM.

#### *Adaptive co-management*

It is well recognised that biosecurity is a complex and uncertain matter (Barker et al., 2013). QFly management is no exception. While protocol documents, such as the QFly management Code of Practice, may suggest that QFly management is a matter of simply

following a set of specifications, regional QFly management is complicated by the fact that each region is unique and knowledge gaps remain in QFly management involving insecticide-based approaches (Clarke et al., 2011). Moreover, the management of AWM programs is known for being managerial intensive and complex due to the technical, social, institutional and financial dimensions involved (Vreysen et al., 2007b).

Adaptive management is recommended to deal with uncertainty, complexity and surprise in SESs (Folke et al., 2005). Fundamentally, this involves a cyclical process of 'learning by doing', monitoring and reflection, where learning from past and current management activities shape the approach applied in the following stages of the resource management process (Olsson et al., 2004; Allan and Curtis, 2005; Marshall, 2005; Stankey et al., 2005; Røling and Wagemakers, 2000; Stringer et al., 2006; Prager and Vanclay, 2010; Holling, 1978), including in the context of pest management (Shea et al., 2002). It is seen as a complementary approach to more conventional resource management that tends to rely heavily on reductionist thinking and one-way transfer of generic information (Allan and Curtis, 2005). The adaptive management concept was formally introduced in the late 1970s by Crawford Holling (Holling, 1978), followed by Carl Walters who further developed the rationale in the mid-1980s (Walters, 1986).

In addition, the concept of co-management promotes knowledge partnerships involving shared power, rights and responsibilities in relation to managing natural resources (Plummer and FitzGibbon, 2007; Berkes, 2009). It involves bringing together different networks and organisations (Olsson et al., 2004), including those of resource users, scientists, government managers, and other stakeholders. This enables management strategies to engage with various knowledge systems, horizontally at the local level and vertically across jurisdictional levels (Armitage et al., 2008b) as a continuous problem-solving process (Plummer, 2009; Berkes, 2009). Some of the earliest key scholars who formally introduced this concept include Fikret Berkes (e.g. Berkes et al., 1991), Evelyn

Pinkerton (e.g. Pinkerton, 1994; Pinkerton, 1992) and Robert Pomeroy (e.g. Pomeroy, 1995; Pomeroy and Pido, 1995).

An increasing body of literature combines the notions of adaptive management and co-management as a prudent governance approach for SESs in the form of adaptive co-management (Armitage et al., 2008a; Plummer and Hashimoto, 2011; Plummer and FitzGibbon, 2007; Olsson et al., 2004; Doubleday, 2007; Wollenberg et al., 2000; Cundill and Fabricius, 2009). Armitage et al. (2008b: p96) define the concept of adaptive co-management as *‘a flexible system of resource management, tailored to specific places and situations, supported by, and working in conjunction with, various organizations at different scales’*.

Hence, adaptive co-management typically involves collaboration among diverse actors who self-organise through voluntary coordination and self-enforcement activities with a strong focus on learning (Ruitenbeek and Cartier, 2001; Olsson et al., 2004; Cundill and Fabricius, 2009). This approach contributes to achieving institutional fit between ecosystems and governance; that is, how well institutions themselves fit together and with the biophysical and social arenas in which they function (Plummer and Hashimoto, 2011). Key facets include social learning, communication, adaptive capacity, shared decision-making and shared authority (Plummer and Armitage, 2007). These were used as a lens to investigate fruit fly AWM in Article 2.

However, biosecurity traditionally involves a positivist technocratic mode of thinking (Reed and Curzon, 2015) based on objective and absolute knowledge as is evident from the large volumes of technical pest-related literature (Schut et al., 2014) (see also section 1.4.2).

Internationally and within Australia there are also concerted efforts for more harmonisation and standardisation of biosecurity practices (Higgins et al., 2016). A key example is the IPPC’s ISPMs and Australia’s QFly management Code of Practice. It is not uncommon that formalised and generalised knowledge displaces local knowledge in the

biosecurity context (Enticott and Wilkinson, 2013). Communication with grower and other communities generally rely heavily on top-down, generic information provision (Royce, 2011). Knowledge hierarchies occur in the biosecurity context that determine whose knowledge counts, normally in favour of certain scientific groups (Enticott and Wilkinson, 2013, Bickerstaff and Simmons, 2004). While not disregarding ‘expert’ knowledge, Enticott and Franklin (2009) warn that it should not be privileged at the expense of local knowledge and learning processes rooted in the local socio-economic, cultural and political contexts (Gonsalves, 2005).

Local people construct their own understandings of why they should or should not do certain biosecurity practices based on their own and their peers’ interpretation of the validity of recommended practice. These decisions are further influenced by practical considerations and competing sets of priorities across all areas of their lives. In addition, people normally know exceptions to the rules. For example, farmers may point to a farming operation that contracted a biosecurity issue despite adhering strictly to recommended practice and/or others who are not following recommended practice and who have not been affected by the relevant biosecurity risk. This can undermine their faith in universal biosecurity knowledge (Enticott and Wilkinson, 2013).

### **2.2.2 Community collaboration**

There is a need for community collaboration to enable successful AWM, as host plants in town backyards, peri-urban areas and on public land can present pest breeding places (Vreysen et al., 2007a; Klassen, 2005). Hence pest management activities are also required in non-commercial urban settings. Article 3 investigates what policy interventions are best suited to secure community collaboration to deal with horticultural pest pressure coming from private land beyond affected commercial orchards.

The role of the community has received considerable attention in NRM literature, including those relating to biosecurity. Broadly, two coexisting theoretical views are evident. The first is commonly called public participation, which revolves around capturing important information and views from stakeholders that contribute to the success of managing SESs. The public participation approach tends to increase the perceived legitimacy and satisfaction with decisions and outcomes (Moore and Rockloff, 2006; Lane, 2005; Stringer et al., 2006; Parkins and Mitchell, 2005; Lockie and Vanclay, 1997; Curtis and Sample, 2010; DeCaro and Stokes, 2013; Carlsson and Berkes, 2005; Curtis and Lockwood, 2000). Public participation is also seen as bolstering stakeholder empowerment and local control (Parkins and Mitchell, 2005), while encouraging participants to voluntarily implement on-ground activities (Lane et al., 2004). Participatory processes and multi-stakeholder participation are central themes in both the adaptive management and the co-management literatures (Stringer et al., 2006; Carlsson and Berkes, 2005; Armitage et al., 2010).

Public participation rose to prominence in the 1960s and the theoretical background to public participation is rather scattered and intertwined with theoretical work from other fields (Webler, 1999; Rowe and Frewer, 2005). Listing them all falls outside the scope of this study. Key influential works include Jürgen Habermas' theory of communication, including his theory of communicative action (Webler, 1999; Habermas, 1984; Habermas, 1985) that emphasises quality deliberation processes to ensure effective decision-making (Reed, 2008; Dietz and Stern, 2008). The seminal work by Sherry Arnstein (1969) also has had a large influence on subsequent work about public participation. She identified different forms of participation and the power (or lack thereof) citizens have in influencing outcomes. In this work she questions to what extent attempts to involve the public are tokenistic, thereby lacking the needed redistribution of power to make these interactions meaningful.

The second view of the role of the community in NRM is contained in neoliberal thinking. Further to the discussion in Chapter 1, the shift towards neoliberal economic management in Australia during the last few decades, including the New Public Management approach, means that governments are now viewed as facilitators of progress and development rather than direct actors in agriculture and other economic sectors (Rose, 2000; Gill, 2011; Wissemann et al., 2003). Osborne and Gaebler (1992) famously coined this as government's role shifting from 'rower' to 'steerer'. This is manifested in the state pursuing governance, rather than governing, in a bid for industries to be more self-reliant. In other words, a shift from a single governing body, such as the state, to the sharing of governing activities between the state and non-state participants (Dibden et al., 2011). In particular, cross-sector partnerships are seen as a key vehicle to mediate the changed roles and responsibilities of society's three primary institutional sectors, i.e. government, business and the civil sector.

Associated with the neoliberal push towards public-private partnerships is an increased emphasis on the community as an active agent and mobilising active citizens (Joseph, 2013). The concept of 'community' has become increasingly popular as a solution to the individualistic, market-based approaches of neo-classical thinking (Cheshire and Lawrence, 2005). Key neoliberal themes such as deregulation and a smaller state led to the term 'roll-back' neoliberalism (Peck, 2010; Maye et al., 2012; Lockie and Higgins, 2007), which results in increased reliance on voluntary approaches to address NRM issues (Gunningham, 2009). Hence, neoliberal approaches easily lead to a way of thinking that emphasises what the community can do to achieve predetermined outcomes.

Some biosecurity scholars question whether endowing biosecurity responsibilities to citizens in general is appropriate, such as the need to undertake voluntary biosecurity-related activities. In particular, there is concern about the limited input citizens have in determining the objectives of these activities (Barker, 2010). Some argue that if people are

asked to contribute to achieving certain biosecurity objectives, they should have the opportunity to influence the related biosecurity agendas. If not, it could be argued that they are taken advantage of for the benefit of other groups in society (Donaldson, 2013).

Article 3 outlines why both rationales are problematic in the context of community collaboration for AWM of QFly. In particular, AWM is used as an example of a situation where the main beneficiaries (growers) are concentrated, yet the costs are diffused across many risk contributors. It argues that there is a need for 'smart regulation'. 'Smart regulation' involves the employment of a range of complementary policy instruments and behaviour interventions fit for a specific context (Martin and Gunningham, 2014; Australian Public Service Commission, 2009; Kennedy, 2010). It is defined as 'a form of regulatory pluralism that embraces flexible, imaginative and innovative forms of social control' (Gunningham and Sinclair, 2017: , p133). For example, it may combine regulation, self-motivation and local empowerment. In other words, given the neoliberal context of biosecurity, this article argues for a shift to 'roll-out' neoliberalism. That is, the introduction of policy adjustments that still support 'market rule' (Peck, 2010; Maye et al., 2012), but that overcome the shortcomings of relying on voluntary approaches to gain community collaboration.

### **2.3 The theoretical underpinnings of Phase 2**

This phase takes as its departure point that local industries will require a range of knowledge, capabilities and resources in order to achieve industry-driven AWM. As Klerkx and Leeuwis (2008) point out, growers are likely to face challenges, such as information asymmetries and difficulty in finding providers who can meet their information needs. So they may lack certain competencies that will withhold them from initiating AWM programs. Hindrances are likely to be present at various points, such as the knowledge and skill level of individual growers, the accessibility of information, the nature of the new

technologies, the characteristics of the industry and how stakeholders interact with each other (Morris et al., 2006). Innovation is therefore needed, not only to produce new technologies, but also to design the institutional context to ensure local industries can readily access the needed information and support (Klerkx et al., 2010).

It is important to make a distinction here between the term ‘systems approach’ as a phytosanitary measure and ‘systems approach’ as put forward in innovation systems theory literature. In this document ‘systems approach’ refers primarily to the phytosanitary measure that the IPPC defines as: *‘The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests’* (IPPC, 2013: p22). In innovation systems literature the term ‘systems approach’ generally refers to the notion that innovations emerge from systems of actors, who are embedded in an institutional context that influences how they behave, link and interact with other parts of the system (Hounkonnou et al., 2012; Hall et al., 2003; Jacobsson and Bergek, 2011; Allen et al., 2011). The prevailing institutions, actors and interactions in addition to technology development all offer entry points to strengthen innovation (Hounkonnou et al., 2012).

### **2.3.1 Agricultural Innovation Systems**

An Agricultural Innovation Systems (AIS) approach was chosen as the theoretical underpinning for Phase 2 as innovation systems approaches are valuable to assist in understanding the macro-level socio-economic and political context (see for example Kebebe et al., 2015) (refer to Figure 1, Chapter 1). In particular, AIS offers a way to explore how multi-level, multi-actor and multi-dimensional dynamics shape plant biosecurity innovation outcomes (Schut et al., 2014). An AIS can be defined as *‘a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance’* (World Bank, 2006: pvi-vii). Innovation here, therefore, means the process of



both technical and institutional change at farm and higher levels that impacts on outcomes such as productivity, sustainability, and market access (Röling, 2009). Given the changing conditions for QFly management and the need for innovative approaches for both pest suppression and market access arrangements, applying AIS thinking is well suited to address research question 2 (Phase 2).

AIS is a corollary of the innovation systems approach, which originated in the mid-1990s in Europe in response to what was seen as deficiencies in neoliberal and neo-classical economic approaches (Jacobsson and Bergek, 2011). It became increasingly apparent that high levels of research seldom lead to high levels of innovation and societal development, especially in the case of ‘wicked problems’. This phenomenon is called the ‘knowledge paradox’ (Bouma et al., 2011).

The innovation systems approach perceives innovation not as the result of science or markets, but rather of interaction between actors to collectively pursue progress. Actors are heterogeneous with their own interests, perspectives and values. Hence, such collective action involves deliberations, negotiations, tensions, agreements between actors and engaging in collaborative efforts that determine whether advances are made (Röling, 2009; Van Mierlo et al., 2010). Unlike reductionist approaches, the innovation systems concept acknowledges that the system’s behaviour cannot be understood by a sole focus on analysing different key components. Instead, exchanges and interactions between different components are a fundamental element of understanding the functioning of an innovation system (Hall and Clark, 2010).

Innovation systems are, therefore, interconnected institutions where knowledge, skills and technologies are created and transferred (Van Latesteijn and Andeweg, 2010). They acknowledge that institutions, unlike technologies, cannot be merely designed, tested or replicated, but they are embedded in historical contexts (Röling, 2009; Hounkonnou et al.,

2012). The result is a complex knowledge and economic system involving various feedback loops where information and resources flow between its components and across boundaries. Learning plays a central role (Hall and Clark, 2010).

A range of innovation system approaches have emerged, including the ‘national innovation systems’ (Lundvall, 1992). The key contribution of this concept is that it provides policy-makers with a tool to identify systemic weaknesses that obstruct the development and performance of the system. This assists with policy interventions (Jacobsson and Bergek, 2011).

Subsequently, the AIS concept originated in the 2000s and was developed from the ‘national innovation systems’ literature (Lundvall, 1992; World Bank, 2006; Hall et al., 2001). It emerged as a critique to prevailing linear models of agriculture innovation, where innovations are developed by scientists and then transferred to farmers. Similar to the other innovation sectors, many studies demonstrated that innovations developed by scientists are often not adopted by farmers and other agriculture stakeholders (Leeuwis and Aarts, 2011).

Based on widespread evidence, successful agricultural innovations are now seen as the result of multiple interactions between growers, supply chain members, research bodies, markets, authorities, policies and other elements (Leeuwis and Aarts, 2011; Klerkx et al., 2012b; Bouma et al., 2011). The different actors engage in a process of co-learning and negotiation to shape the innovation (Klerkx and Leeuwis, 2008). Here, organisational arrangements, such as agreements, rules and perceptions, are seen as part of the innovation system, rather than external conditions (Leeuwis and Aarts, 2011).

AIS comprises a co-evolutionary process involving concomitant technological, institutional, social and economic change. It is not a neutral process, but is driven by values, norms and worldviews that bring about winners and losers (Klerkx et al., 2012b). Successful innovation therefore depends on changed narratives, discourses that come about between

the interacting agents (Leeuwis and Aarts, 2011). Klerkx et al. (2010) posit, in reference to Giddens' structuration theory (Giddens, 1984), that as individual actors lack power and resources to pursue innovation on their own, they need the support and cooperation of others. Actors are therefore conditioned by their network, while also actively shaping it to achieve their own and collective goals (ibid.).

A key component of AIS is its emphasis on the importance of intermediaries or knowledge brokers who act throughout different parts of the innovation system's multi-actor networks (Kilelu et al., 2013). Their key bridging functions include demand articulation, knowledge translation, network formation and coordination and innovation management functions (Kilelu et al., 2013; Klerkx and Leeuwis, 2008). These are further described in Article 4 below. The importance for knowledge brokering between disparate groups related to a biosecurity issue is also increasingly highlighted (Reed and Curzon, 2015; Thompson et al., 2009; Proctor et al., 2011). For example, Proctor et al. (2011) show how professionals advising farmers—in their case vets—not only transfer scientific knowledge to them, but also 'translate' different kinds of knowledge, while developing new knowledge 'by doing'.

Where multiple stakeholders are involved there is also a need for innovation platforms, that is, spaces that are deliberately created to facilitate linkages between heterogeneous stakeholders that enable information-sharing, knowledge-development and implementation activities to solve a common problem (Cullen et al., 2014; Kilelu et al., 2013). For issues that require addressing across levels, such as across local, state/territory and national levels, there may be a need for interconnected innovation platforms (Nederlof et al., 2011). This is further discussed in Article 5.

This resonates with suggestions made by several biosecurity scholars who call for more 'alternative spaces of negotiation' that allows for more negotiation and flexibility (Higgins et al., 2016; Enticott, 2008). Cook et al. (2010) suggest the formation of local 'grower

cooperatives’ as part of a more adaptive governance approach to biosecurity. The purpose of these groups is to act as local governance hubs. They are then linked to inter-connected hubs across levels. A key aim is to ensure information flows not only ‘top-down’ but also ‘bottom-up’ and horizontally between ‘grower cooperatives’. In this process scientific findings can be integrated with local and other forms of knowledge.

Schut et al. (2014) investigated to what extent innovation systems thinking are found in the crop protection literature. They concluded that the potential of AIS to deepen understanding about how to address complex crop protection challenges is left mainly unexplored. This work contributes to filling this gap.

AIS thinking is also complementary to adaptive co-management thinking because both AIS and adaptive co-management embrace the need for social interaction in the way of open, pluralistic and democratic processes that are underpinned by social learning to engage with complexity. Both rationales promote close integration between science and social choice (e.g. policy-making), as the application of knowledge is seen as value-laden (Norton, 2005).

Key overlapping themes between adaptive co-management and AIS are listed in Table 1.

**Table 1. Overlapping themes between adaptive co-management and innovation systems (including AIS).**

<b>Common themes and focal points</b>	<b>Adaptive co-management</b>	<b>Innovation systems/AIS thinking</b>
Institutional interplay	Armitage et al. (2008b); Berkes et al. (2007)	Leeuwis and Aarts (2011); Klerkx et al. (2010)
Networks, including cross-scale/multi-level linkages	Armitage et al. (2008b); Carlsson and Sandström (2007); Cash et al. (2006); Berkes et al. (2007); Bodin et	Leeuwis and Aarts (2011); Klerkx et al. (2012b); Klerkx and Nettle (2013); Klerkx and Leeuwis (2008);

<b>Common themes and focal points</b>	<b>Adaptive co-management</b>	<b>Innovation systems/AIS thinking</b>
	al. (2006); Folke (2007)	
Learning (including social learning)	Armitage et al. (2008b); Cash et al. (2006); Berkes et al. (2007); Allen et al. (2011)	Hall and Clark (2010); Klerkx and Leeuwis (2008); Klerkx and Nettle (2013); Knickel et al. (2009)
Complex systems thinking to overcome reductionist approaches and deal with complexity and uncertainty	Armitage et al. (2008b); Cash et al. (2006); Berkes et al. (2007); Allen et al. (2011); Folke (2007)	Hall and Clark (2010); Knickel et al. (2009); Klerkx and Leeuwis (2008)
Knowledge brokers/ Intermediaries/Bridging organisations	Cash et al. (2006); Bodin et al. (2006); Allen et al. (2011); Berkes (2009)	Klerkx and Nettle (2013); Klerkx et al. (2012a); Kilelu et al. (2013)

### **2.3.2 The functional-structural analysis approach**

While the concept of AIS is now well established, different approaches are applied to analyse them (Klerkx et al., 2012b; Turner et al., 2016). The Phase 2 research applies a process-oriented, functionalist view of AIS (Klerkx et al., 2012b) as proposed by Hekkert et al. (2007) to understand how particular weaknesses hinder the fulfilment of certain functions. The functional-structural approach of innovation systems was further developed by Wieczorek and Hekkert (2012) by adding the structural components of innovation systems. These components include the presence of actors, their interactions, institutions and infrastructure (Nelson, 1993; Wieczorek and Hekkert, 2012; Turner et al., 2016; Jacobsson and Bergek, 2011). Whereas the functions of innovation systems represent the

processes that support healthy innovation systems, the quality of the structural components make it possible for the innovation system to function (Wieczorek and Hekkert, 2012; Kebebe et al., 2015). This work argues that a well-functioning innovation system will support entrepreneurs, here local industries, in their endeavours to capitalise on new opportunities (Hekkert et al., 2007), here AWM. The structural components offer target areas for policy recommendations to strengthen the innovation functions (Jacobsson and Bergek, 2011; Kebebe et al., 2015).

Like other studies (such as Lamprinopoulou et al., 2014; Turner et al., 2016; Kebebe et al., 2015), Phase 2 involves a combined functional-structural analysis of the current QFly innovation, in particular how it interacts with and supports industry-driven AWM programs. The seven functions proposed by Hekkert et al. (2007) is used as a lens in order to identify systemic weaknesses that could provide opportunities for improvement. This is done both in the context of growers securing support to achieve AWM for pest suppression (Article 4) and to include AWM as part of a systems approach to achieve access to QFly-sensitive markets (Article 5). The weaknesses are then listed against the different structural components to assist in identifying policy intervention recommendations.

The seven functions are interpreted as follows:

*F1. Entrepreneurial activities* – actors exploit opportunities by arranging new knowledge and networks into initiatives. This represents conducting experiments, including taking risks with uncertain markets, technologies and institutions (Jacobsson and Bergek, 2011; Negro et al., 2007). These activities are indicators of the system's performance as they produce knowledge about the innovation system's functioning in various settings. Well-functioning innovation systems will assist entrepreneurial activities to thrive (Hekkert et al., 2007).

*F2. Knowledge development* – this is normally a strong function in innovation systems (Jacobsson and Bergek, 2011). The most important mechanism here is learning, which can come from ‘learning by searching’ (e.g. formal research, engaging expertise from elsewhere) or ‘learning by doing’ (Hekkert et al., 2007; Negro et al., 2007).

*F3. Knowledge diffusion* – this involves multi-directional information flow that encourages learning by interacting with others and by applying certain technologies or approaches (Hekkert et al., 2007). This involves not only the latest research findings and policy decisions reaching growers or other target audiences, but for different players in the innovation network to influence the agendas of others. For example, on-ground challenges and opportunities also need to reach and shape the agendas of policy-makers and technology developers (Negro et al., 2007). Sound communication is fundamental here as the meaning of knowledge is actively constructed between people and these meanings are influenced by context and prior knowledge. Failed communication is likely to contribute to misunderstandings and other problems and tensions (Leeuwis and Aarts, 2011).

*F4. Guidance of the search* – this encompasses stakeholders' vision that gives direction to the innovation process. The use of limited resources is optimised if learning processes across levels are directed based on external influence and continuous internal interactions and reflections (Hekkert et al., 2007). This includes making the needs and expectations of entrepreneurs and technology users visible (Negro et al., 2007).

*F5. Market formation* – this refers to investing effort and resources into creating markets for products produced in new ways as they face competition from what users are accustomed to (Hekkert et al., 2007; Negro et al., 2007).

*F6. Mobilisation of resources* – this comprises the human and financial capital that are needed for all activities in the innovation process (Hekkert et al., 2007; Negro et al., 2007). Hence,

this function includes influencing actors in how and where to invest resources (Jacobsson and Bergek, 2011).

*F7. Creation of legitimacy* – resistance to new technologies and approaches needs to be surmounted (Hekkert et al., 2007). Innovations need to become part of the current regime or even replace existing systems or technologies (Negro et al., 2007). Legitimacy is also vital for other functions to perform, such as resource mobilisation, market formation and guiding the direction of the search. It cannot be taken for granted and often requires a concerted effort to overcome the uncertainty associated with newness (Jacobsson and Bergek, 2011).

AIS thinking is seen as complementary to the SESs Framework as it also conceptualises innovations such as AWM as a nested set of systems within other systems (Hekkert et al., 2007). Moreover, several innovation systems studies use as their departure point the structural components of innovation systems, that represent some overlap with those presented in Figure 1 (Chapter 1), including the actors, their interactions, the governance system or institutions (Ostrom, 2009; Wieczorek and Hekkert, 2012). Both the SESs Framework and the AIS approach recognise that the social and governance structures and accompanying institutions influence the behaviour of actors, while actors might also be part of the governance system and shape the prevailing institutions (Binder et al., 2013; Klerkx et al., 2010).

Little evidence was found that a functional-structural analysis of a biosecurity-related system has been done before. However, several parts of the biosecurity literature refer to similar principles as those contained in the innovation functions. For example, AIS literature points out that in most innovation systems knowledge production tends to be the strongest function, in particular scientific knowledge production (function 2) (Jacobsson and Bergek, 2011). This is likely even more so for biosecurity in Australia given the related



neoliberal technocratic discourses that construct biosecurity challenges as technical issues in need of technical solutions. In addition, the push for harmonisation and standardised practices (Higgins et al., 2016) could give the impression that the only need for knowledge diffusion (function 3) is to communicate prescribed activities to farmers (Enticott, 2008). However, as suggested above as part of the discussion about *Adaptive co-management* under 2.2.1, social scientists focusing on biosecurity increasingly call for broader kinds of tacit and non-tacit knowledge to be integrated when solutions are constructed and tailored to circumstances. Biosecurity knowledge diffusion is required not only ‘top-down’, but also multi-directional including ‘bottom-up’ and horizontally between actors to increase the co-production of integrated knowledge (Kruger et al., 2009; Falk et al., 2009; Enticott and Wilkinson, 2013; Pautasso et al., 2012).

There is considerable evidence of guidance of the search (function 4) in the both Australian biosecurity and fruit fly management at national level. This is evident from strategic documents that have been developed through wide stakeholder consultation such as the National fruit fly strategy and its related Implementation plan (NFFS Implementation Committee, 2009) and the National fruit fly research, development and extension plan (Plant Biosecurity CRC, 2015).

In terms of resource mobilisation (function 6) much attention has been given in biosecurity literature to the costs and benefits related to fruit fly AWM and the need for cost sharing between government and industry (e.g. Florec et al., 2013; Kalang Consultancy Services, 2008; Chambers and Franco-Dixon, 2007; Ha et al., 2010; Harvey et al., 2010; Mumford, 2000; Florec et al., 2010). A key argument for industry contribution is that industry is the main beneficiary. For example, Abdalla et al. (2012) argue that fruit fly management constitutes an industry rather than a public good as it is specific industry members that benefit from fruit fly management through reduced production losses and strengthened trade opportunities. Arguments for public sector investment include the difficult challenge

of dealing with ‘free-riding’ that is outside the control of farmers, and the public benefits that are derived from reduced pesticide use (Hendrichs et al., 2007).

## **2.4 Methods**

This section outlines the methods used throughout the research reported in this thesis. At the start of research project a literature review was carried out. It covered the key paradigms and discourses that influence how fruit fly management is framed and approached (see Chapter 1) and the social and institutional aspects of AWM of pests and SESs. Later literature about community engagement, AIS, and agricultural extension was also explored.

### **2.4.1 Phase 1 – Case study research**

After the initial literature review, qualitative research based on a case study approach was applied in Phase 1 to gain an in-depth understanding of the processes occurring at the local level (Denzin and Lincoln, 2000).

#### ***Rationale for case study research***

Several reasons exist for the choice of a case study approach. It is a popular approach for studying collective action in NRM, as it provides rich, in-depth knowledge about a certain combination of events and circumstances (Agrawal and Chhatre, 2006; Meinzen-Dick et al., 2004; Poteete et al., 2010). As a complex adaptive system, the socio-institutional aspects of AWM cannot be understood by studying separate elements (Marshall, 2005). Case studies enable investigating a phenomenon as a ‘whole’, including understanding the complex relations and teasing apart closely interwoven variables to create a detailed understanding of the phenomenon studied (Poteete et al., 2010). In particular, it enables understanding how local people socially construct their realities through their own interpretations and by interacting with others (Blumer, 2007). Case studies offer a valuable way to investigate areas where knowledge is shallow, fragmented, incomplete or non-existent (Punch, 2005).

Poteete et al. (2010) identify a case study approach as the only option for empirical field-based research when cross-case data is limited. The use of multiple cases provides a stronger base for theory building than a single case, as propositions and theoretical constructs are more deeply grounded in empirical evidence from a broader exploration of research questions. Each case study in effect presents a trial, here of fruit fly AWM, under different conditions and together they contribute to the emerging theory (Eisenhardt and Graebner, 2007). Comparative analysis between case studies strengthens the validity of each individual case's findings through data triangulation. This benefit is maximised when the cases are subjected to a single research design, as opposed to case study comparisons between different projects (Marshall, 2005). Hence this study involves three case studies.

#### *Case study selection*

Case studies were selected using theoretical sampling. In other words, cases were chosen to maximise gaining insight (Eisenhardt and Graebner, 2007; Flyvbjerg, 2006) about the social and institutional aspects of fruit fly AWM programs as opposed to random sampling. They were also chosen to achieve maximum variation of social and institutional profiles (Flyvbjerg, 2006). The selection criteria for the cases were that they all had to involve existing, or coordinated, attempts to achieve industry-driven fruit fly AWM programs in Australian horticultural industries. In addition they had to have different social and institutional profiles. An overview of the case studies is provided in Chapter 3. It is noteworthy that despite the fact that fruit fly AWM programs are increasingly in the spotlight as a strategy to address fruit fly issues, incidences of industry-driven AWM programs in Australia are still limited.

#### *Case study fieldwork*

Fieldwork occurred between September 2013 and March 2014. This involved face-to-face, in-depth, semi-structured interviews with key informants. One focus group was also carried out for each case study, predominantly with the management group members.

Purposive sampling was used to select interviewees by identifying suitable people based on their knowledge, position or characteristics (Morse et al., 2002), such as how well they know how growers and/or the broader community respond to the AWM program. This provided an opportunity to focus on a small, but information-rich sample to address the research questions. A range of interviewees were chosen to ensure a diverse range of perspectives (Eisenhardt and Graebner, 2007). Key informants typically included local program coordinators, key growers, on-farm consultants, as well as representatives of the programs' management groups, packhouses, local shire councils and local industry bodies and associations. The great majority of interviews were carried out face-to-face with only a few completed over the phone when, for example, a state government representative was not living in the region visited. The interviews were audio-recorded.

Entering a study relating to a SES warrants a broad perspective as SESs literature, including the SESs Framework, presents an analytical challenge with its large number concepts, variables and possible interactions, (Armitage, 2007). Interview and focus group questions were broad and open-ended in order to obtain an authentic representation of how respondents view the local AWM program 'from the inside' (Punch, 2005). The interview questions were aimed at understanding research question 1, i.e. how the prospects of successful industry-driven AWM can be increased at the local level from a social and institutional perspective. To do this the interview questions were framed around the SESs Framework tier 1 components (see Figure 1, Chapter 1). The key questions were based on the themes listed below (the SESs Framework components are at the end of each theme in brackets). For more detail about the questions asked during the Phase 1 interviews, see Appendix 1.

- How does the AWM program operate – including progress to date, how it is currently being managed, how rules are being set and if consequences exist for lack of QFly management (Action situation, AWM governance system and outcomes)

- Who are the main players in the AWM program and how do they contribute? Who should be contributing more? (Actors)
- What communication processes are used with and between different stakeholders about QFly and the AWM program? (Interaction and feedback between governance system and actors)

Focus groups were used to develop a timeline of key QFly-related events in each region and to explore:

- What does success look like?
- What has worked well about the QFly management so far?
- What are the main challenges to achieve or maintain AWM?

### *Data analysis*

Soon after each field trip, the audio recordings of the interviews and focus group discussions were transcribed verbatim. This was to ensure that the data used involved accounts that are as true as possible to the original source thereby minimising the risk of data loss or misinterpretation (Green and Thorogood, 2013). Data was analysed by using the qualitative research analysis tool NVivo, as such software assists in achieving a high level of consistency as well as reliable coding, categorisation and comparison of data (Bazeley and Jackson, 2013). For all three case studies, coding revolved around broad categories relating to the AMW program and the key players. These nodes were:

- ‘Local AWM program’, including sub-nodes on things such as ‘background’, ‘rules’ (of operation), ‘challenges and positives’
- ‘QFly management in the region’, including sub-nodes such as ‘history’, ‘perceptions of QFly’ and ‘management techniques’

- Key players nodes included the ‘Australian Government’; ‘state government’; ‘local government’; ‘industry bodies’; ‘landholders’; ‘towns’; and ‘management group’. Sub nodes typically included things such as ‘communication’ (to and from), ‘rules’ and ‘learning’ associated with each group
- Markets
- Other contextual issues

Having a data set for each case study assisted in easier data interrogation for each case study. As they all had the same broad coding structure it allowed for easy comparison between cases. There were variations in nodes and sub-nodes to better match the data to each case study. For example, Central Burnett had an additional node for on-farm ‘crop consultants’, as these players were a key part of this AWM program. Structuring the data in this format provided a sound starting point for the analyses needed for the first three journal articles.

For example, journal article 1 (see section 4.1) applied Ostrom’s design principles for robust common-pool resource institutions. Different sets of nodes and sub-nodes related to each principle and this facilitated finding the relevant information. For example, Principle 1 ‘Clearly define boundaries’, drew on sub-nodes such as ‘AWM program’/’background’; ‘AWM program’/’rules’; ‘landholders’/’supportive’; ‘landholders’/’not supportive’; and ‘towns’. Principle 2 ‘Congruence between appropriation and provision rules and local conditions’ drew predominantly on ‘AWM Program’/’background’; and ‘AWM program’/’rules’.

Journal article 2 (see section 4.2) applied the key components of adaptive co-management (Plummer and Armitage, 2007) to the case studies. Again, certain nodes and sub-nodes related to each component. For example, the first two components discussed involved

social learning and communication. As sub-nodes around ‘learning’ and ‘communication’ were created for most key players (which formed parent nodes), they provided key areas for locating relevant data. For the components of adaptive capacity, shared decision-making and shared authority the parent nodes about the ‘local AWM program’ and the related sub-nodes assisted with finding the relevant information. For the component shared authority the nodes around the three levels of government and markets were also key areas to locate the needed data.

Journal article 3 focuses on the challenge of gaining community collaboration (see section 4.3). The nodes relating to ‘towns’, ‘local government’ and ‘landholders’/’not supportive’ were key points for information, in addition to data from the grower survey.

### ***Validation***

Member checking of interview responses (Punch, 2005) was adopted for all three case studies. Participants were provided with a summary of the findings developed from NVivo using the parent nodes for the structure of these documents. It allowed them to identify gaps or provide alternative views to the points listed. Key representatives of each case study were also provided with draft copies of the journal articles to allow them the opportunity to comment and be informed about what had been produced from the research findings.

In addition, in order to bolster the robustness, thickness and richness of the evidence base, methodological triangulation was used, that is, converging lines of inquiry based on multiple methods and sources of evidence (Denzin, 1973; Punch, 2005; Denscombe, 2014). Data from the semi-structured interviews and focus groups were supplemented with data, where available, from relevant meeting minutes, media releases, journal articles and other documents about the local initiatives.

### *Case study research limitations*

A key limitation of the case study research is that it is based on three case studies across two states only. Even though the case selection deployed in this thesis captured theoretically important variation, it is likely that more lessons can be drawn from studying cases in other regions across Australia.

Another limitation is that significant developments occurred in the two New South Wales case study regions after the fieldwork was carried out, that is, the instigation of systems approach trials. This work does not report on these events and the related stakeholder experiences.

#### **2.4.2 Phase 2 – Semi-structured interviews about the institutional context**

The key research question for Phase 2 was how can an enabling broader institutional environment for industry-driven fruit fly AWM be created? Phase 2 started with the development of a list of the key knowledge, capabilities and resources that local industries need to achieve fruit fly AWM for market access. The draft list was based on the case study research and then galvanised through consultation with seven key informants, including case study representatives, and research and government officials involved in either the technical or market access aspects of AWM.

Subsequently, between April and September 2015, semi-structured interviews were carried out with key informants who work in the broader institutional and support network of fruit fly management. Semi-structured interviews are a common approach for studies that apply Hekkert's seven functions and/or a combined functional-structural investigation (see for example Negro et al., 2007). As for Phase 1, purposive sampling was used to select interviewees, i.e. people were chosen based on their knowledge, position or characteristics (Morse et al., 2002), such as being appointed in a fruit fly-related role, and having extended involvement in fruit fly management, research or policy-making and/or engagement with



growers and others about the pest. This was complemented with ‘snow-balling’, that is, requesting key people to suggest others to be interviewed (Noy, 2008; Denscombe, 2014). This enabled an information-rich sample, here involving 33 interviews with 36 participants (some interviews involved more than one person). A range of interviewees were chosen to ensure diverse range of perspectives (Eisenhardt and Graebner, 2007). The types of individuals interviewed are listed in Table 2.

As the case studies are located in New South Wales and Queensland, Phase 2 interviewees were predominantly located in these two states. Due to the scattered location of the interviewees the project budget did not allow for travel to all interviewees. Thirteen interviews were conducted face-to-face, nineteen by phone and one respondent preferred to respond in writing. Audio recordings were made of all interviews, which were transcribed verbatim afterwards. Due to time constraints, the great majority of audio recordings were transcribed by a professional transcriber.

**Table 2. The representation and number of Phase 2 interviewees**

Organisation represented	No. of interviewees
State government – QFly researcher	7
State government – Policy	6
State government – Industry support	4
State government – Operational management	1
Australian Government – Policy	3
University sector	2
Industry body	7
Local industry	2
Local government	1
Consultant	3

Interview questions were designed to assist in understanding the current institutional context and answering how a more enabling broader institutional environment for fruit fly AWM could be created. Hence, interview questions explored:

- the role of the interviewees and/or the organisation represented in advancing QFly on-ground management and/or market access
- the main barriers faced in supporting local industries with on-ground QFly management and/or achieving market access to QFly-sensitive markets
- from their perspective, the key knowledge and capabilities that local industries need to achieve AWM for suppression and/or market access (they were also asked to comment on the draft list of key knowledge and capabilities required developed earlier)
- the potential for AWM as part of a systems approach to underpin market access (only for interviewees involved in market access)
- how local industries can secure the support they need to achieve AWM
- how support for local industries can be improved.

Feedback from interviewees was used to refine the list of key knowledge, capabilities and resources that local industries need to achieve fruit fly AWM for market access. The final list is contained in Appendix 2.

Data was also obtained by reviewing fruit fly governance publications. These include:

- Draft National Fruit Fly Strategy (PHA, 2008)
- National Fruit Fly Strategy – Draft Implementation Action Plan (NFFS Implementation Committee, 2009)

- National Fruit Fly Research, Development and Extension Plan (Plant Biosecurity CRC, 2015)
- Regional prioritisation of the National Fruit Fly Research, Development & Extension Plan (Metcalf, 2015)

### *Data analysis*

As mentioned earlier, an inductive-deductive interplay between using and developing theory was applied (Eisenhardt and Graebner, 2007). In other words, when data coding started there was no commitment to a particular theory yet. However, the researcher kept exploring literature while the interviews were on-going, in particular literature relating to agricultural research, development and extension; and AWM. When the data collection and analysis were well under way, it became clear that several key themes emerging from the data resonated well with AIS thinking. These included that high emphasis on formal knowledge and technology creation is often accompanied by the assumption that these will be adopted by industry (linear model). The data showed that various other factors also slowed progress at the on-ground level, such as that local industries are often weakly linked to other key QFly management innovation system actors. As AIS thinking suggests a holistic approach to solving the agricultural problems by improving the related innovation system, it offered a suitable approach to understand how to create an enabling environment for industry-driven AWM.

The functional-structural analysis approach proposed by Bergek et al. (2008) and Wiczorek and Hekkert (2012) seemed particularly relevant as the functions represent processes that would make entrepreneurial activities flourish (Negro et al., 2007; Hekkert et al., 2007). In other words, finding ways to achieve/support all functions is likely to create an enabling environment for local industries pursuing AWM. Applying the functional-structural analysis was selected during the data analysis phase.

Data coding from the interview transcripts involved an iterative process of constant checking and refining codes as new data came in. As the author conducted the interviews and made notes during and shortly after the interviews, it assisted with familiarity with the data (Denscombe, 2014; Punch, 2005). Coding ('open coding') started around key stakeholder groups, i.e. Australian Government, state governments, local government, community, and industry bodies. As themes across, or not related to, specific stakeholder groups became apparent, additional parent nodes were added. As the connections between the open codes started to emerge, it enabled axial coding (Punch, 2005).

Hence, continuous refining of codes happened during the data analysis, including refining code names and categorising and re-categorising of codes as needed. Sometimes a parent node became a child node. For example, one such parent node was 'CoP out of date' (QFly management Code of Practice is out of date), which was an early open code. Over time more issues related to the Code of Practice appeared that went beyond the document being seen as out of date, such as prescriptions for the use of certain traps that were hard to come by. The name of the parent node was changed to 'CoP', with child nodes 'CoP out of date' and 'Other challenges'.

Sometimes a parent node became a child node of another parent node. For example, there used to be two parent nodes titled 'need inter-scale approach' and 'industry and government interaction important'. Later the latter became a child node of the former. From time to time previously coded transcripts were revisited to ensure coding remained consistent.

Later the seven functions and structural components were added as nodes. Many of the existing nodes were allocated to these. However, to ensure nothing was overlooked, all transcripts were reviewed again.

### ***Validation***

All interviewees received a copy of their interview transcript to provide them with the opportunity to correct or add anything if needed. This led to a few small corrections. A respected industry representative who has had a long involvement with QFly management in Australia was engaged to critically review drafts of the last two articles (chapters 4.4 and 4.5) and interpretation of the data to ‘ground truth’ the findings.

### ***Limitations***

The limitations of Phase 2 include that it has an *ex-post* character. That is, in the current fast-moving arena of fruit fly management, conditions have changed since the interviews took place and interviewees’ information might not have been current (Lamprinopoulou et al., 2014). This research also represents a snapshot of a difficult transitioning period in Australia’s QFly management. It occurred after an era when growers had access to the low-cost, easy-to-apply pesticides of dimethoate and fenthion and several areas had more on-ground state government support. Yet the research was also conducted during the time when new initiatives, such as the National Fruit Fly Council, the SITplus program, the AWM Coordinator and the National Fruit Fly Research, Development and Extension Plan (Plant Biosecurity CRC, 2015) came about. As not enough time has passed for them to show real impact, this may have impacted interviewees’ responses. The social and institutional aspects of AWM uptake as part of the SITplus program is being explored by the SITplus program partners.

#### **2.4.3 Phases 1 and 2 – Grower survey**

A grower survey was instigated to complement the qualitative data obtained through both Phases 1 and 2. It represents methodological triangulation and increases the findings’ richness (Denscombe, 2014). The survey was conducted in all three case study regions between September and November 2015. The survey was designed based on themes that came from the qualitative research in Phase 1 and informal discussions with QFly key

informants. It covered aspects of on-ground QFly management and how growers related to the broader QFly system, such as the levels of trust that various stakeholder groups would deliver the needed support and cooperation. The survey is included in Appendix 3. In short, the survey asked respondents about:

- how they were impacted by QFly
- if they used crop consultants
- their management of QFly on non-commercial land, such as host plants around the farm house and sheds
- their opinions about different control mechanisms, including their cost-effectiveness and ease of application
- their levels of trust in different stakeholder groups to provide cooperation or support relating to both QFly suppression and market access to QFly-sensitive markets. For QFly suppression these included full-time growers, part-time growers, town residents, the management group, the local government and the state government. For market access these were the local management group, state government and federal government.
- their understanding of some market access concepts
- their views about who should be responsible for QFly management, i.e. government, industry or both.

The survey questions were designed and refined in consultation with a few key growers, crop consultants and management group members across all three case studies. This was to ensure that the questions asked were appropriate for the growers targeted, both in context and the way they were worded. Questions related to market access were asked only of

growers who are interested in supplying to QFly-sensitive markets. Many questions requested respondents to rate to what extent they agreed or disagreed with a statement, with the options being ‘strongly disagree’, ‘somewhat disagree’, ‘somewhat agree’, ‘strongly agree’ and ‘I don’t know’. The survey was hosted on the online service SurveyGizmo.

Grower contact lists were provided by either the local management group or the local industry association, which, to the best of their knowledge, included all growers in the region representing the industry driving coordinated QFly management. All lists needed data cleaning, as some entries were either out of business or the phone numbers did not function. The response rate has been calculated based only on the entries that were contactable and operating (see Table 3).

In order to encourage responses, several suggestions put forward in the survey guidelines by Dillman et al. (2014) were applied:

- the surveys were promoted before they were launched. The sponsorship of peak and/or local industry bodies as legitimate organisations was employed. They assisted with promoting the survey by emailing growers to encourage their support. Media releases through the local media were also published where possible shortly before the survey was introduced to further raise the profile of the survey.
- communication with growers was on an adult-to-adult basis, pointing out that other growers in the region also participated and emphasising the benefits of participating. The benefits were that the survey findings would strengthen the ‘grower voice’ in the policy arena and academic circles by showing what AWM looks like from an on-ground perspective. All growers were contacted by phone to request their participation.

- growers were offered multiple ways to complete the survey. It was emphasised that online completion through SurveyGizmo was the quickest and easiest. If they agreed they were emailed an invitation letter, an information sheet outlining what would happen to their data and a link to the survey. They were also offered a hard copy with a paid return envelope if they preferred not to use a computer. Alternatively, they were able to choose to complete the survey over the phone.
- they received several well-spaced reminders in different formats. Respondents were given around six weeks to complete the survey. SurveyGizmo's functionality allowed for sending an electronic reminder after a week. Those who still had not responded after 10 to 21 days received another reminder phone call. After another approximately 10 days those who had not responded received a final reminder phone call and/or email.

The response rate was calculated based on the 'clean' data list; that is, the growers who were contactable and operating, including those who from the onset declined and those who initially agreed but failed to complete the survey. The lower response rate from the Riverina is in part due to lower levels of computer usage in this region. Here there were many more requests for hard copies and this region had a lower return rate than did the electronic survey. This was probably because hard copies are more cumbersome to return.

In Young-Harden two cherry growers indicated that they were not affected by QFly and were therefore not doing anything to manage the pest. Like for the other local industries not affected by QFly, these growers were not included in the sample group. The survey response rates are outlined in Table 3.

There were a number of limitations to the conduct of the survey:



- The initial intention was to survey all horticulture growers in each region. However, survey responses from wine grape growers in Young-Harden, the first area where the survey was launched, quickly showed that responses from horticulture growers not impacted by QFly resulted in a high level of ‘I don’t know’ responses. Consequently, it was decided to continue surveying only growers who were part of the industries that are driving coordinated QFly management.

**Table 3. Grower survey response rates**

	<b>Central Burnett (QLD)</b>	<b>Young- Harden (NSW)</b>	<b>Leeton &amp; Carrathool (Riverina, NSW)</b>
No. of growers requested to participate (‘clean’ list)	40	28	98
No. of respondents	28	20	50
Response rate	70 %	63%	51%
No. of respondents interested in QFly-sensitive markets <sup>1</sup>	26	12	22

<sup>1</sup> Only these growers answered questions related to accessing QFly-sensitive markets.

- In Young-Harden there are a number of cherry growers with a non-English speaking background who are known to seldom participate in local industry activities. For example, the local industry association has not been able to include them in their grower list. Various attempts were made to contact them and request their participation, but to no avail.

- The large size of the Riverina, project resourcing and time constraints prevented surveying all citrus growers in the region. As a matter of courtesy, the Riverina QFly campaign coordinator was asked to liaise with Riverina Biosecurity Incorporated (the management group) to identify a sample region. This resulted in the local government areas of Leeton and Carrathool becoming the participating areas. According to the qualitative research findings, some respondents see these as the more progressive regions in the Riverina, including having a better chance to achieve cooperation between growers.
- Due to the small population sizes, the findings presented in the articles are limited to percentages of respondents only. It was not possible to do statistical analysis beyond descriptive in nature.

## 2.5 Ethics

A core element of good research is ethical research. Identifying what constitutes ethical human research has been a long on-going point of enquiry among scholars. Most notable in the last century were the Nuremberg trials and a number of other human research related scandals, such as the 'Tuskegee Syphilis Experiment'. In response certain principles now stand central to many countries' research ethics guidelines (MacFarlane, 2010; Lindorff, 2010), including Australia's National Statement on Ethical Conduct in Human Research (NHMRC et al., 2007). As the ANU Human Research Ethics Committee base their requirements for ethical clearance on the Australia's National Statement on Ethical Conduct in Human Research, the principles contained in the Statement underpin this research. They are:

- *Justice* – this implies the research will not exploit participants, for example, by overburdening them in terms of time, energy, discomfort and disclosure; or because they are for whatever reason vulnerable. Research outcomes and findings

need to not reinforce or strengthen injustices or inequalities (Lindorff, 2010; NHMRC et al., 2007)

- *Beneficence* – acting for the benefit of others (MacFarlane, 2010), therefore research needs to be designed to minimise risks of harm and maximise potential advantages to participants, their families and related communities (Lindorff, 2010; NHMRC et al., 2007)
- *Respect* – to treat others as oneself would like to be treated (MacFarlane, 2010), including to have due regard for participants' autonomy, such as for their beliefs, perceptions and cultural backgrounds, as well as their privacy and confidentiality (Lindorff, 2010; NHMRC et al., 2007)
- *Research merit and integrity* – including research that is justifiable based on the potential benefit it offers; designed such that the methods and resources are appropriate for achieving its objectives; supervised by experienced people; and is peer reviewed (NHMRC et al., 2007).

With these principles in mind, the research proposals associated with each phase were developed and subsequently submitted and approved by the ANU Human Research Ethics Committee. The research activities included the case study fieldwork, the semi-structured interviews with key informants active in the broader QFly network and the survey.

As part of the ethics applications, plain language program information sheets were developed for each activity. The program sheets provided information about what the project was about; what was required from participants; the time their involvement would take; the option of withdrawal at any time; confidentiality; how their data would be used and stored; and the benefits, if any, they could expect from the study.

Consent forms were produced to obtain participants' formal consent to participate in either a focus group or interview and for the conversation to be audio-recorded. The consent form for focus groups also included a statement that the participant agreed to keep the comments of others in the group confidential. All participants agreed to have interviews and focus groups audio-recorded, although some requested the recorder to be turned off during some parts of the interview. As growers self-opted to participate in the survey, their participation was regarded as giving consent.

## Chapter 3. The case studies

This chapter describes key features of the case study regions, why they were chosen and the key findings. As mentioned in Chapter 2, case studies were selected to achieve maximum variation of social and institutional profiles (Flyvbjerg, 2006). As successful industry-driven AWM programs in Australia were still scarce, both existing, and coordinated attempts to achieve industry-driven AWM programs were considered. The case studies are Central Burnett in Queensland, which has attained AWM, plus Riverina and Young-Harden are both in New South Wales and are working towards AWM. Figure 3 provides an overview of the case studies' locations.

Note that systems approach trials were initiated in 2015 in both the Riverina and Young-Harden with the support of the NSW Department of Primary Industries (NSW DPI). As these developments occurred after the fieldwork they are not covered here.



Figure 3. An overview of the case study locations

### **3.1 Central Burnett (Queensland)**

Central Burnett was chosen as it is seen as a model case of successful industry-driven AWM (Davidson and Davidson, 2012; PHA, 2008; Hargreaves and Nimmo, 2012; Fay et al., 2011). Once a significant endemic pest that sometimes devastated crops, QFly is now a minor pest. Past trap catches revealed up to 240 flies/trap/day, but this reduced drastically to 1 fly/trap/day by 2010 under the AWM program (Fay et al., 2011)

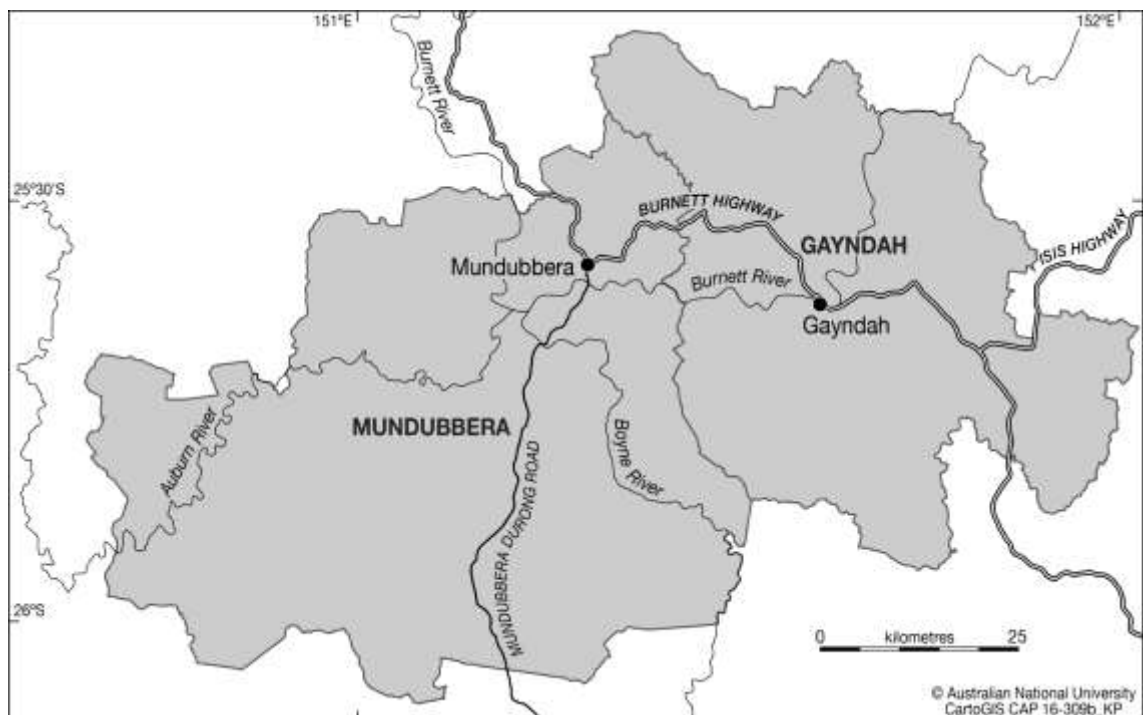
Preliminary investigation before the project commenced suggested that Central Burnett has had certain social factors that contributed to its success, which could be easily overlooked when the focus is only on the technical aspects of the program. These included the strong involvement of local crop consultants in the AWM program. Town communities were also dependent on the local citrus industry for the region's economic well-being and residents were thus sensitive to the industry's needs (Lloyd et al., 2010).

Central Burnett presented a form of critical case as it involved social circumstances in which the success of the phenomena under investigation was most likely (Flyvbjerg, 2006). Fieldwork here was carried out in October 2013, involving thirteen semi-structured interviews and a focus group.

#### **3.1.1 Regional and grower community profile**

The area under AWM is located in the local government area (LGA) of North Burnett Region and it surrounds the towns of Gayndah and Mundubbera as indicated in Figure 4. The area had an estimated 2000 hectares of citrus (mainly mandarins) and 50 hectares of mangoes in 2007 (Fay et al., 2011). AWM strategies are applied in the citrus growing area on either side of the Burnett River. Most commercial orchards are located along the Burnett, Boyne and Auburn Rivers and their tributaries. This region is about 70 km long and 12 km wide (Lloyd et al., 2010). Gayndah and Mundubbera are the only town areas included in the AWM program (Lloyd, 2007).

No official record of the number of citrus growers in the region could be found. At the time of the fieldwork, some respondents estimated that there were around 60 commercial citrus growers. However, once the survey contact list was cleaned of non-operating numbers, 40 entries were left. In some cases several farms had the same owner. There were also small numbers of table grape and mango growers. Citrus growers were fairly homogenous in their on-farm goals relating to QFly. For example, 93 per cent of survey respondents were interested in supplying to QFly-sensitive markets.



**Figure 4. The Central Burnett district**

From a biophysical point of view, the area is surrounded by dry sclerophyll forests and grazing land (Lloyd et al., 2010) that have a protective affect as a natural barrier to QFly infestation from outside the region. QFly activity is low in the period when citrus is maturing and harvested, that is, between March and August. However, QFly prevalence surges in spring, with temperature increases from late August and early September (Lloyd et al., 2010).

### **3.1.2 History**

The AWM program builds on a successful integrated pest management (IPM) program implemented and refined by on-farm consultants, which had significantly reduced QFly pressure prior to AWM (Lloyd et al., 2010). These activities include trapping, regular protein baiting and occasional insecticide cover sprays at times of high QFly pressure. The then Queensland Department of Primary Industries (QDPI) had carried out a number of QFly-related research activities in the region since the 1990s. Many growers participated in experimental trials with the on-going support of the crop consultants. Hence, fruit fly activity in the area was well understood and provided important baseline data when AWM started as a pilot program. AWM was introduced largely in response to the imminent restricted use of dimethoate, to further improve QFly control and strengthen market access (Lloyd, 2007).

### **3.1.3 Local organisation**

The past Central Burnett Horticulture Committee had been active in the region for many years, as a local research and development body funded by local grower levies. It co-funded a variety of local research projects in the years leading up to AWM, including on IPM, market access, plant breeding, production and fruit quality.

Three local crop consultants had serviced around 90 per cent of growers for twenty years or more (Lloyd, 2007). The survey confirmed reports during the interviews that this figure had reduced somewhat in recent years, mostly due to harsher economic conditions, with 79 per cent of respondents then employing a crop consultant. This is still much higher than the other two case studies (see below). Overall high pest pressure in this region has been proposed as one of the key reasons why so many Central Burnett growers employ consultants. Together the crop consultants form a trusted and credible communication



‘infrastructure’ with growers that allows for ample opportunity for two-way communication and continued support with QFly management.

The Central Burnett AWM Committee was formed in 2003, when the program started as a trial (Lloyd et al., 2010). Until today the committee comprises the three crop consultants, citrus and non-citrus grower representatives from both Gayndah and Mundubbera grower groups, staff from the state government department responsible for agriculture, a local shire council representative and a few other stakeholders.

#### **3.1.4 Securing local cooperation**

There was common agreement during the interviews that a high level of QFly control exists on-farms because several growers had witnessed crops being devastated by QFly some decades ago. The towns of Gayndah and Mundubbera are relatively small (1789 and 1042 residents, respectively in 2011 (ABS, 2014a)), making it feasible for growers to fund urban backyard QFly treatments with voluntary contributions. Earlier QDPI research had ascertained that towns present considerable ‘breeding hot spots’ (Lloyd et al., 2010), which provided clear evidence for the need to apply town treatments.

The key requirement of town residents at the time of the fieldwork was to permit a contractor to enter their backyards to perform control activities. Engagement processes with town residents commenced before the program started, including public meetings, advertising, and media releases (Lloyd, 2007). QFly displays are also presented at public events in the region.

The number of growers making voluntary contributions to the town treatments has reduced considerably over time. This has forced less intense town treatments, although the effectiveness of the revised procedures are being closely monitored. The management committee has been experimenting with approaches to expose those growers who are not contributing in the hope that it will motivate them to contribute again. For example, non-

contributors are made known in an indirect way by publicly thanking contributors in the local newspaper, including listing their names. Contributors are also provided with gate signs.

The most frequently mentioned reason why growers opt out from contributing to town treatments is because others do not contribute, yet still enjoy the same benefits. The survey revealed that 89 per cent of respondents believe that QFly pressure from towns posed a serious risk if left unmanaged. However, 59 per cent indicated that they would contribute to the town treatments only if all other growers contributed as well. The second most mentioned reason is the failure to achieve international market access to lucrative markets without the need for cold sterilisation (see below).

### **3.1.5 Market access**

QFly management through the IPM program has resulted in successful outcomes. This enabled the establishment of a systems approach-based protocol (ICA-28) for Central Burnett citrus founded on pre-harvest baiting and post-harvest inspection for the period from March to late August. In 1999, ICA-28 enabled Central Burnett to secure market access to Victoria without the need for post-harvest treatments (Lloyd, 2007). In 2007, based on this protocol, domestic market access was expanded to South Australia and New South Wales. While there is no requirement for AWM in ICA-28, the project team interpreted this success as increased confidence in the AWM program that complemented the protocol (Fay et al., 2011).

However, access to international markets without the need for post-harvest treatments has not yet been obtained despite the success of the Central Burnett AWM program. Instead, growers are required to invest in cold sterilisation to provide assurances to QFly-sensitive markets that the risk of produce being a source QFly infestation has been adequately addressed.

### **3.2 The Riverina (New South Wales)**

Preliminary scoping revealed that the Riverina could be a challenging case study as the region is large, including the five LGAs of Carrathool, Griffith, Leeton, Murrumbidgee and Narrandera. The region includes many horticulture industries, including citrus, wine grapes, prunes, stonefruit, cherries, figs, apple, walnut and avocado (Davidson and Davidson, 2012). The population is culturally diverse and there was evidence that the town communities lacked knowledge about QFly management in their backyards (Clarke et al., 2012).

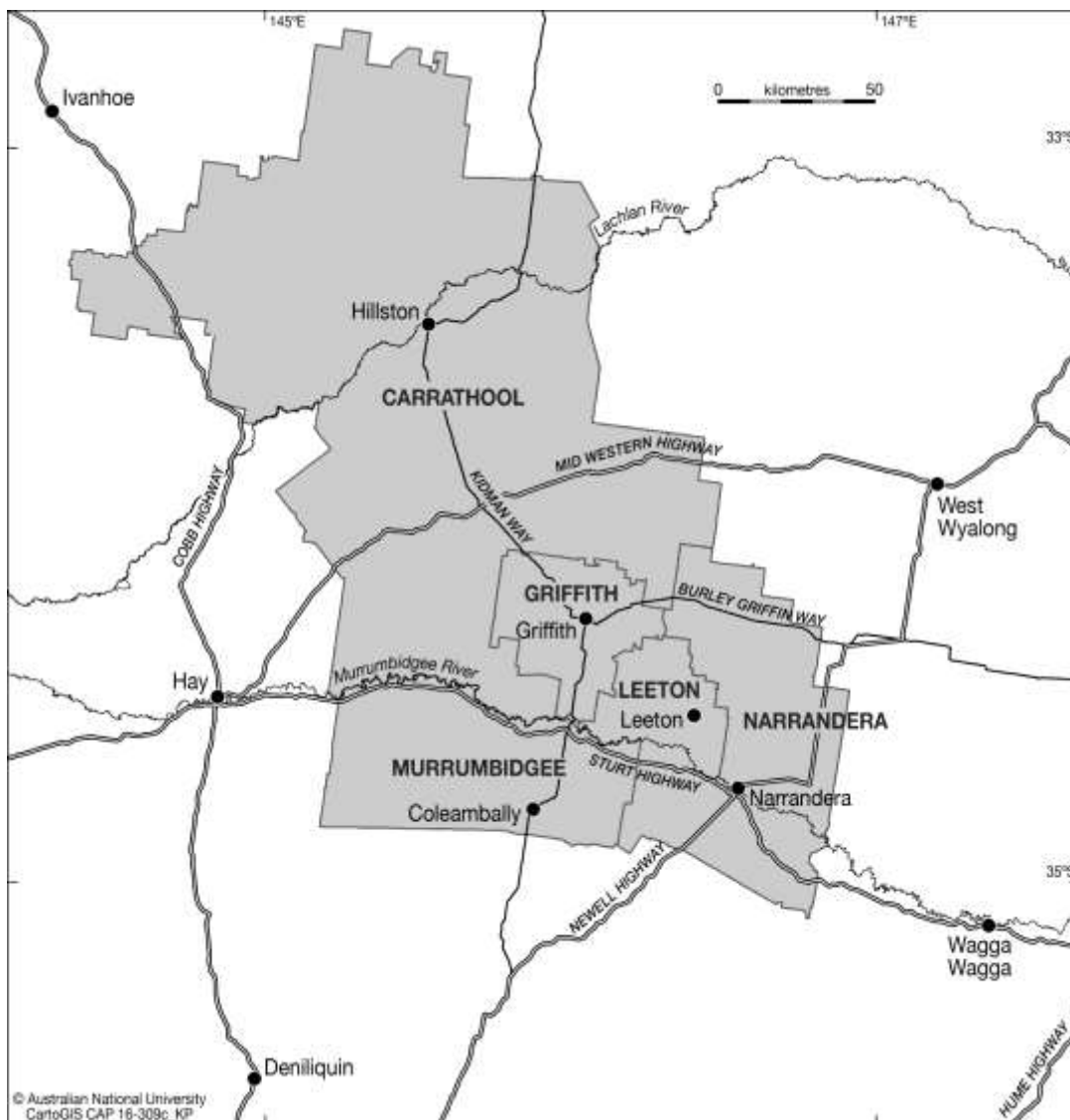
The key drivers for QFly management in this extensive area are to control pest numbers, prevent post-harvest treatments and to minimise impacts on market access opportunities. A business plan for a grower-driven fruit fly control campaign was released in July 2012. This included calls for attitudinal and behavioural change amongst Riverina horticulture growers in how they approached QFly management (Davidson and Davidson, 2012). The fieldwork occurred in March 2014, comprising twenty semi-structured interviews and a focus group. Limited fieldwork resources meant that only two of the five LGAs in the Riverina could be surveyed in 2015. The local management group opted for Leeton and Carrathool. The fieldwork findings suggested that these two LGAs are more progressive than the other regions.

#### **3.2.1 Regional and grower community profile**

According to feedback from respondents in March 2014 there are around 420 citrus, 370 wine grape and 55 prune growers, with several growers being multi-commodity producers. Several towns are also present, including the large rural centre of Griffith, as well as the smaller towns of Leeton, Narrandera and Hillston.

Biophysically, the Riverina's climate is predominantly dry and semi-arid with hot summers and cool winters (RDA, 2014). The Riverina is situated on the ecological limit of the range

for QFly and the area offers marginal conditions for the pest (Yonow and Sutherst, 1998). However, the region encompasses the Murrumbidgee and Coleambally Irrigation Areas (RDA, 2014), and this irrigation makes conditions more suitable for QFly (Yonow and Sutherst, 1998). Dominiak et al. (2006) found that towns over the size 10,000 residents are likely to create micro-climates, i.e. ‘urban heat islands’, which make them more suitable for QFly than surrounding rural areas. This applies to Griffith, which in 2011 had a population of 17,616 residents (ABS, 2013).



**Figure 5. The Riverina area**

Several major roads lead through the Riverina, which increases the risk of travellers carrying fresh produce unwittingly introducing QFly to the region as indicated in Figure 5.

These include the four federal highways of the Hume Highway (north to south), the Sturt Highway (east to west), the Mid-Western Highway (south to north-east), and the Cobb Highway (north to south). The Newell Highway is a principal freight and tourist route connecting Queensland, New South Wales and Victoria. The Sturt Highway is part of the main route between Sydney and Adelaide. Other major highways in this region include the Burley Griffin Way and the Kidman Way (RDA, 2014).

### **3.2.2 History**

The Riverina has a long history of AWM for QFly with strong support from the state government. Yet at the time of case study selection in early 2013, the state government was in the process of handing over QFly on-ground control activities to local horticulture industries. The Riverina used to be part of the Fruit Fly Exclusion Zone (FFEZ), an official trade zone across the adjoining high value horticulture regions in New South Wales, Victoria and South Australia. The official zone was instigated in 1994 to maximise its export market access by eradicating fruit flies from the zone and nearby areas. The zone involved a collaboration between state government and the Australian Government departments responsible for agriculture and several related industries (Voullaire and Dominiak, 2003; Dominiak et al., 2006).

NSW DPI withdrew its management and financial support for the on-ground operations of QFly control in July 2013 and handed these over to industry (NSW DPI, 2012). This followed record numbers of QFly found in the region's trapping grid during the seasons of 2010/11 and 2011/12 (Davidson and Davidson, 2012). Hence NSW DPI deemed the NSW FFEZ economically unsustainable.

One of the key differences in on-ground support is that NSW DPI is now monitoring a hugely reduced number of QFly traps in the area. The trapping grid involved a network of traps across the region that was regularly checked by NSW DPI staff to obtain data about

the number of QFly in the region. This served as hard evidence of the region's QFly status during trade negotiations with overseas countries. There used to be more than 300 traps in the region, which number has been reduced to around 40 traps.

In addition, a local industry body, Riverina Citrus, ceased to exist in March 2012 following local tension about its management. It used to be a key player in QFly-related activities, for example, by working closely with NSW DPI and local shire councils to undertake QFly treatments in towns.

### **3.2.3 Local organisation**

Riverina Biosecurity Incorporated (RBI) was instigated in September 2012 by the now-defunct Riverina Citrus and Citrus Australia as a body to oversee biosecurity issues across horticulture industries, using QFly as a starting point (Davidson and Davidson, 2012). A part-time Riverina Fruit Fly Campaign Coordinator was employed in early 2014 to support the activities of RBI. This was funded by the then Horticulture Australia Limited.

At the time of the fieldwork, the RBI Executive Committee comprised representatives from Citrus Australia, the then Horticulture Australia Limited, Local Land Services, NSW DPI, Leeton Citrus Grower Association, Griffith Citrus Grower Association and Riverina Citrus growers. Representatives of the grower associations are growers themselves. RBI is resourced with residual funding from the now-defunct Riverina Citrus and that originated from citrus grower levies.

The grower survey revealed that a very limited number of growers, involving 30 per cent of respondents, employ a crop consultant. As Leeton and Carrathool are seen as the more progressive regions in the Riverina, this figure is expected to be higher here than elsewhere in the Riverina. Some respondents ascribed the lower level of crop consultant employment to the overall lower pest pressure in the region and the low-input nature of many operations.

### **3.2.4 Securing local cooperation**

RBI attempts to increase grower support for the program by requesting supply chain members, such as packhouses, to insist on proof of QFly control from their grower suppliers. Supportive packhouses typically require growers to provide evidence through spray diaries and receipts for input purchases for QFly management. RBI's fruit fly campaign encourages town residents to manage QFly on their properties. It includes QFly management workshops, publishing articles in local media and promoting QFly management via the radio and TV.

Despite the Riverina being traditionally not endemic to QFly, achieving widespread cooperation faces several social challenges. These include a highly fragmented grower population and diverse on-farm objectives. Many of the non-citrus horticulture industries are not economically affected by QFly and were reluctant to support RBI's efforts. Many citrus growers are part-time operators who run low-input production systems focused on the juice market, while a smaller proportion of growers supply to export markets. Tension within the citrus industry also resulted from the demise of Riverina Citrus in 2012.

Communication with target groups is challenged by a cultural divide between people from different ethnic backgrounds, as well as from different sub-regions in the Riverina.

Several respondents perceive QFly pressure from the towns as beyond the control of growers, while others said town communities are used to government or others taking care of the QFly problem. There are several abandoned orchards in the area which are believed to provide breeding hotspots for QFly.

At the time of the fieldwork legislation required Riverina residents to maintain QFly host plants. According to the Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order No. 45, 2011 under the Plant Diseases Act 1924, owners and occupiers of land or premises in the Riverina area are required to treat citrus and prune

plants for QFly by using specified bait sprays and maintaining a treatment record. Many interviewees expressed frustration that the state government did not enforce this legislation, some ascribing it to a lack of state government resources. A state government representative pointed to a moral constraint upon fining ordinary citizens for not maintaining fruit trees if they lacked resources or were not able-bodied (such as some retirees).

### **3.2.5 Market access**

Most horticulture growers have experienced limited impact from fruit fly on their ability to market their produce, except for export-oriented citrus growers. Forty four percent of survey respondents indicated that they are interested in supplying to QFly-sensitive markets. As noted above, this figure is probably lower in parts of the Riverina other than in the Leeton and Carrathool LGAs. As the trapping grid density no longer meets the requirements for underpinning export market access, lucrative export markets, such as the US, China and Japan, can now only be supplied if produce undergoes costly cold sterilisation.

Most of the citrus supply chains require QFly-free produce; but the prerequisites for supplying growers differ. At the time of the fieldwork juice companies carried out fruit inspections for signs of QFly maggots when produce arrived at the plant. For export-oriented growers to achieve access to lucrative overseas markets without applying cold sterilisation, they must be able to provide evidence that QFly is under control. In the past this was achieved through the extensive trapping grid monitored by NSW DPI when the region was part of the FFEZ. There is little benefit for the juice market growers to invest in such an elaborate and expensive undertaking as area-wide trapping.



### **3.3 Young-Harden (New South Wales)**

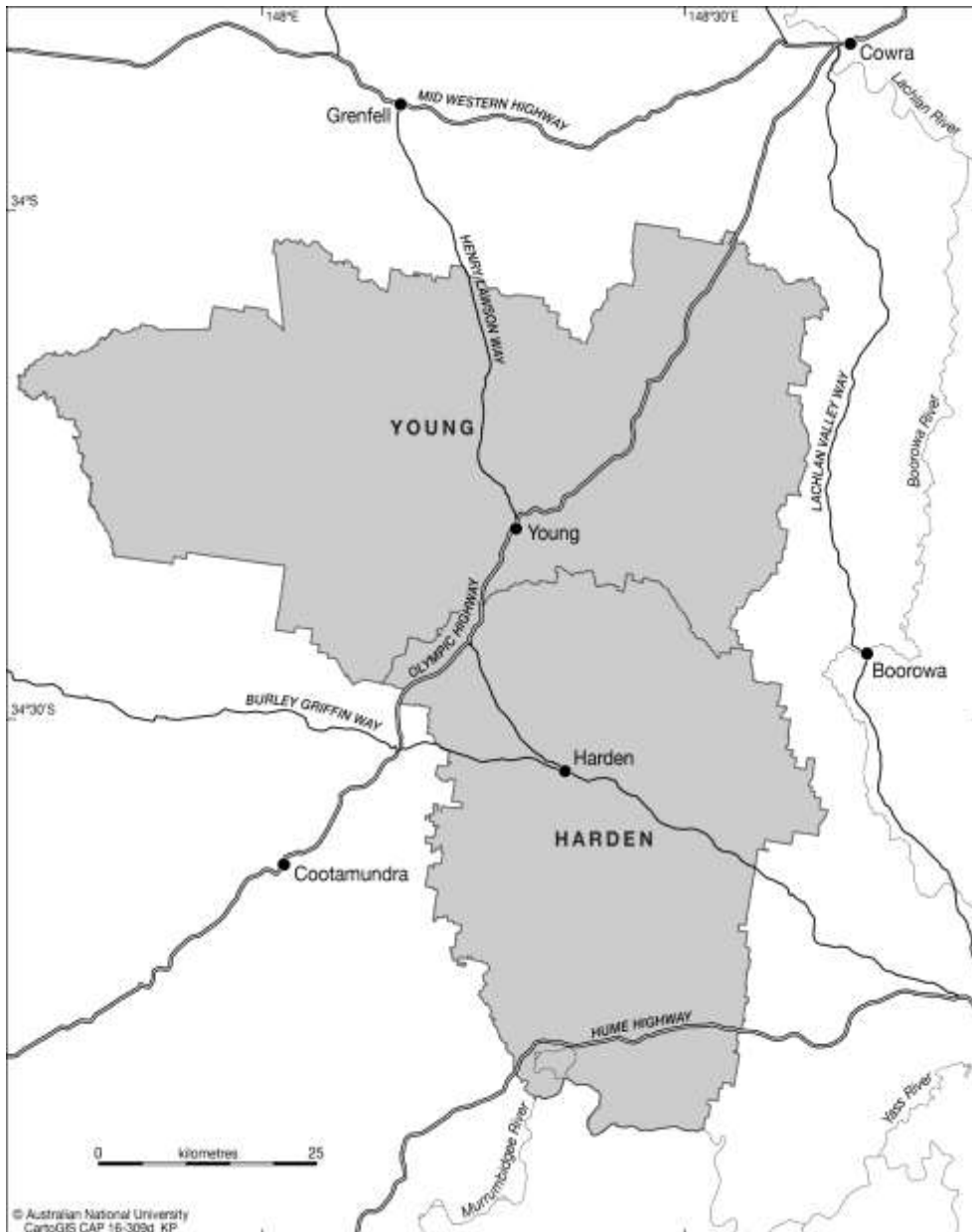
The cherry industry is driving the quest for coordinated QFly control in the region due to market access concerns. A key characteristic of this case study is the strong support it enjoys from the regions' local governments. The fieldwork here was carried out in September 2013 and involved nine semi-structured interviews and a focus group.

Several developments, in addition to the system approach trials, have occurred in this region since the fieldwork was carried out. The impacts of these are not covered by this research. They include the introduction of a SIT initiative in the Young township implemented by the Young local government in collaboration with NSW DPI. In 2016 the councils of Harden, Young and Boorowa merged to form the Hilltops Council.

#### **3.3.1 Regional and grower community profile**

This case study includes the then two shires of Young and Harden (Figure 6). Marte (2007) reports that the region involves an estimated 200 growers producing cherries, sugar plums, prunes, apples, wine grapes and other stonefruit. However, local respondents in 2013 reported a large drop in grower numbers in recent years, and, while no official figures could be obtained, locals believe there are in the order of 40 cherry growers. This seems a reasonable estimate, given that for the survey in 2015 the local cherry grower association list of growers revealed 28 active cherry growers (a few others were listed but reported that they went out of business). There are also a number of growers from non-English speaking backgrounds who prefer not to be part of the association. Respondents in 2013 also referred to 20 wine grape growers, which were confirmed by the grower list from the local winegrape grower association. Local industry representatives estimate the region includes 650 to 700 ha of cherries and up to 1,000 ha of wine grapes.

Growers reported being challenged by impractical export protocols and low profitability over recent years as a result of export market loss, oversupply on the domestic market and a strong Australian dollar.



**Figure 6. The Young-Harden region**

The region's cold winter temperatures and QFly pressure during the cherry harvest season were key reasons why this region has previously been identified as suitable for establishing an AWM program (Marte, 2007; Jorgensen, 2002). QFly trapping activity during 2003 and

2006 showed that the towns had considerably higher QFly prevalence than the surrounding commercial orchards (Marte, 2007).

### **3.3.2 History**

Young-Harden has had the least intense history with QFly control in the region although various QFly activities have been carried out by the state government and the local councils (Marte, 2007). Cherry growers lost market access to Taiwan in the early 2000s and to Thailand in 2011, due to QFly-related concerns with the latter being described as a ‘particularly big blow’ to cherry growers.

### **3.3.3 Local organisation**

Cherry growers and the local councils of the Young and Harden shires instigated the Fruit Fly Action Group in September 2012. This group aims to coordinate QFly activities in the region. The Action Group includes representatives from the two councils, an on-farm consultant from a chemical company and a NSW DPI representative. Most growers’ representatives are well connected both with other growers in the region and/or with the cherry industry networks. For example, several grower members are also members of the Cherry Grower Association Board, Australian Cherry Export Working Group, NSW Cherries Association and the then Horticulture Australia Limited advisory committees. One member has been involved in QFly management activities in the past and his local knowledge is highly valued. Some of these growers are collaborating formally and informally with a NSW DPI researcher on QFly-related research activities on their properties.

Anecdotally, persistent ‘nagging’ from one grower who had been particularly hit hard by QFly pressure from towns, played a key role in getting the local government on board. In addition to fulfilling various administrative responsibilities related to the QFly initiative, the

local government applies bait sprays on public land during two periods per year when QFly numbers spike.

A key theme was frustration with the lack of support from the Australian Government to progress market access. Establishing the needed networks was identified as one of the biggest challenges. The Fruit Fly Action Group tries to build rapport with key government officials, such as the State Minister for Agriculture. The group intends to win the cooperation of other horticulture industries in the wider region to have more influence when dealing with politicians about QFly.

### **3.3.4 Securing cooperation**

There were reports that growers find the transition from using fenthion and dimethoate to softer technologies, such as bait spraying, challenging as the latter needs to be applied more regularly and is more costly. Following resource-intensive recommended procedures, such as picking up fallen fruit, is also challenged when profitability is low. For example, picking up fallen fruit after a hail storm is not economically justifiable when a big part of the crop has been destroyed. Thirty percent of respondents in the grower survey indicated that they employ the services of a crop consultant.

Respondents reported that fruit fly breeding in town backyards is a major concern. The community has been approached through articles in local newspapers and newsletters, letterbox drops, occasional reports on the radio and two community meetings. Some mentioned an increase in derelict orchards, lifestyle blocks and absentee landholders on land that used to be commercial orchards. Some exiting growers sold their land as a number of lifestyle blocks to maximise their capital gain.

In the past some town residents complained when local council staff applied chemicals in their backyards to control QFly. The fear that the NSW Environmental Protection Authority might issue considerable fines to the local council in response to public

complaints, contributed to the council ceasing backyard treatments. Several respondents pointed out that, despite the strong support from local government, there is a lack of local power to compel risk contributors to follow recommended best practice. Examples include several town residents, lifestyle block owners and absentee landholders.

#### **3.3.5 Market access**

Despite negligible QFly damage to cherries exported, the pest hampers market access and necessitates cold sterilisation to access several markets. Not only does this add considerable cost, cold sterilisation can cause quality deterioration in cherries and undermine the growers' competitiveness. Sixty per cent of respondents in the grower survey indicated that they are interested in supplying to QFly-sensitive markets.



## Chapter 4. Publications

### **4.1 Article 1. Designing local institutions for cooperative pest management to underpin market access: the case of industry-driven fruit fly area-wide management**

In this article Ostrom's design principles for robust common-pool resource institutions (Anderies et al., 2004, Poteete et al., 2010, Cox et al., 2010, Ostrom, 1990) are applied to case study findings to demonstrate the important influence of regional communities' social profile on their ability to achieve AWM.

## Designing local institutions for cooperative pest management to underpin market access: the case of industry-driven fruit fly area-wide management

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**Abstract:** Area-wide management of mobile pests offers advantages over uncoordinated farm-by-farm efforts through increased effectiveness of pest control and by reducing the need for pesticides. The literature about area-wide pest management focuses predominantly on the technical aspects of these programs, but tends to neglect the importance of social and institutional aspects. In this article the eight design principles for robust common-pool resource institutions are applied to industry-driven area-wide pest management. Three case studies are compared to gain insight about the social and institutional aspects that affect the success of these undertakings. These cases are focused on Queensland Fruit Fly control to underpin market access. Growers face a particular challenge to gain support from town residents, as backyard fruit trees can be pest breeding spots. The paper illustrates that social aspects – such as heterogeneous incentives, social capital and the ratio between town residents and main beneficiary growers – influence the ease of which the design principles can be applied. Market access opportunities impact the ratio of cost and benefits to different participants. The paper concludes that disconnecting the technical aspects of successful programs from the social and institutional aspects in which they are embedded can create unrealistic expectations in socially different regions that intend to replicate these programs.

**Keywords:** Biosecurity, market access, pest management, social ecological systems, sustainable agriculture

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## 1. Introduction

Pests have been a key challenge to sustainable agriculture since the days humans started to cultivate their own food. Nowadays pests are spreading at an increased rate due to rising international movement related to trade and tourism activities (Maye et al. 2012). Governments and agriculture industries in contemporary society use a relatively new term when they refer to this challenge, namely biosecurity. Biosecurity involves designing strategies and activities to minimise and manage the risks related to the spread and establishment of pests, diseases and other undesirable organisms impacting on plant, animal and human health (Outhwaite 2010).

International trade is a key driver for implementing national and international agricultural biosecurity strategies (Maye et al. 2012). International and national legal and regulatory biosecurity measures are in place for the prevention, eradication and control of pests (Outhwaite 2010). This means that the risk of particular pests being present either restricts access to certain overseas and domestic markets or necessitates preventative phytosanitary measures, often at substantial cost to the exporter (Dibden et al. 2011).

Despite the far-reaching implications of pests, they have received relatively little attention as a commons issue. Most biosecurity-related research centres around the economic and biophysical aspects of pest management, while focus on socio-institutional elements has only started to gain momentum during the last decade (Barker et al. 2013). Yet, as will be established, there are many commons-based issues when trying to successfully implement biosecurity measures.

This article explores the case of industry-driven fruit fly area-wide management as a commons issue. In particular, it uses Elinor Ostrom's (Ostrom 1990) design principles for robust socio-ecological systems as a lens to better understand what promotes or hinders collective action. It concludes that the commons theory offer valuable insights to area-wide management. More broadly, it draws attention to the idea that the concept of biosecurity is situated in the world-view of neoliberalism and market supremacy.

## 2. Background

Fruit fly is one of the world's most significant commercial pests affecting horticulture. Several species of fruit fly cost Australia around a total of AUS\$300 million a year in control and lost markets, with more than three quarters of fruit

and vegetable exports susceptible (Plant Biosecurity CRC 2014). In addition, fruit fly management has recently become more challenging in Australia following the restriction of key pesticides traditionally used to control the pest, such as fenthion and dimethoate (Florec et al. 2013), forcing industry to identify alternative measures. This study focuses on Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) or in short, QFly.

In terms of its general biophysical features, QFly is geared for survival. A couple of flies can result in a large population in one season under favourable conditions. QFly has a preference for warmer and wetter weather. Proliferation is limited by extreme high or low temperatures and a lack of moisture. It becomes less active during winter, and in several areas fruit fly pressure in spring is related to whether the region had cold or mild winter conditions (Dominiak et al. 2006).

Traditional pest management typically involves growers reactively addressing pests on a farm-by-farm basis. The trouble with a mobile pest such as QFly is that re-infestation tends to occur from nearby untreated areas, such as backyards, derelict orchards and wild hosts (Klassen 2005; Vreysen et al. 2007b). Hence, proactive, uniform suppression of the total pest population across a region is more effective than the uncoordinated endeavours of individual growers (Hendrichs et al. 2007).

Area-wide management is increasingly in the spotlight as a QFly management solution as it promises a reduced need for pesticides (PHA 2008; Fay et al. 2011; White et al. 2011). It involves synchronised pest management strategies used over a wide geographical area with the aim to reduce QFly either to below economic threat levels or to eradicate it (Elliott et al. 2008). Strategies are applied to commercial horticulture operations and urban settings, such as backyard fruit trees. Area-wide management programs can have different aims, including achieving pest free status, where the pest is fully eradicated and/or excluded, or to maintain so-called areas of low pest prevalence. Several benefit-cost analyses have shown that area-wide fruit fly management can be cost effective (Kalang Consultancy Services 2013; Ha et al. 2010; Florec et al. 2013).

Area-wide management happens world-wide to manage mobile pests, often in combination with integrated pest management and other technologies (Klassen 2007). Fruit fly area-wide programs exist or have been trialled in Argentina, Australia, Brazil, Chile, Central America, Israel, Mexico, South Africa, Thailand, Tunisia and the United States (Vreysen et al. 2007b). Many such programs are instigated to underpin market access and are therefore embedded in the highly regulated, politicised and contested wider institutional context of national and international trade. The World Trade Organisation (WTO), in conjunction with the International Plant Protection Convention (IPPC), promotes international free trade whilst upholding a science-based approach to prevent agricultural trade causing biosecurity risks. The IPPC's international standards for phytosanitary measures (ISPMs) make allowance for fruit fly area-wide management systems, including 'ISPM 26 Establishment of pest free areas for fruit flies' and 'ISPM 30

Establishment of areas of low pest prevalence for fruit flies'. As well, the 'ISPM 35. Systems approach for pest risk management of fruit flies' is also relevant to area-wide management. Systems approaches involve two or more independent measures pre- and/or postharvest to achieve satisfactory phytosanitary outcomes. Areas of low pest prevalence are seen as good candidates to be used as part of systems approaches (PHA 2008).

Australian state governments have traditionally been key contributors in performing on-ground operations to control QFly, especially for pest free areas. However, there is increasingly an expectation that industry will take the lead in funding and managing QFly management programs.

Management of area-wide management programs is intensive and logistically complex. It requires the support and cooperation of a critical mass of owners of host plants. This ranges from high-value produce growers through to town residents with host plants in backyards (Hendrichs et al. 2007). Maintaining public participation is a key challenge (Mumford and Tan 2000). However, it is mostly the technical and economic aspects of QFly that receives most attention in the literature (Dyck et al. 2005). This paper attempts to broaden the problem-solving approach by shedding more light on the socio-institutional factors that influence the success of these undertakings.

This paper argues that low prevalence (or freedom) of a pest within any particular region is a resource presenting a commons issue. All inhabitants who otherwise would have experienced damage from higher pest prevalence enjoy benefits from this resource, whether through less crop damage or via improved marketing prospects. Overall, biosecurity is generally referred to as a public good resource (Perrings et al. 2010; Mumford 2013). However, on-ground mobile pest control resembles a common-pool resource, i.e. a resource with high subtractability and low excludability (Ostrom 2005). Horticulture growers (and other host plant owners) who are not controlling the pest on their properties are reducing benefits to growers who are carrying-out pest control, as the former provides breeding spots for the pest which then harms the resource for all users (implying high subtractability). It is difficult to exclude landholders who are not contributing to pest control from the benefits of low pest prevalence (low excludability).

Hence, the social dilemmas of free-riding and 'opting-out' also apply to mobile pest management. For example, if a critical mass of growers is following recommended practice, thereby reducing QFly pressure, those who are not following suit cannot be excluded from the benefits, i.e. from free-riding. This provides a perverse incentive not to invest in QFly management. Likewise, growers witnessing others doing little to address QFly on their properties could use this observation as an 'opt-out clause' by asking 'Why should I control QFly if they don't?'

A lack of cooperation will result in 'the tragedy of the commons' (Hardin 1968). That is, as some people maximised their short-term benefits by underinvesting in QFly management, QFly has the opportunity to proliferate on their properties



resulting in increased QFly pressure in the region. This is to the detriment of all owners of horticulture crops in the region, regardless whether they are cooperating with recommended practice. The best way to overcome this dilemma associated with the commons is through well-considered local institutions (Ostrom 1990; Anderies, Janssen, and Ostrom 2004).]

### 3. Methods

This study applies the design principles of robust common-pool resource institutions pioneered by Elinor Ostrom and others to three cases of industry-driven area-wide fruit fly management programs. Box 1 contains a short description of the case studies.

#### **Box 1. Short case study description**

##### *Central Burnett, Queensland*

Central Burnett was chosen as it is often held-up as a model case of successful industry-driven fruit fly area-wide management (PHA 2008; Lloyd et al. 2010; Davidson and Davidson 2012). Once a significant endemic pest that sometimes devastated crops, QFly is now considered a minor pest. Preliminary investigation suggested that Central Burnett has social factors that contribute to its success and which tend to be overlooked when the focus is on the program's technical aspects. There are around 60 commercial horticulture growers (predominantly citrus) in the region. One focus group and thirteen interviews were carried out in October 2013.

##### *Riverina, New South Wales*

Preliminary scoping revealed that this large, diversified horticulture region could be a particularly challenging case study. It also includes large rural centres, such as Griffith, that economically depends on a range of service and other industries, and not just horticulture. Traditionally, the region is not endemic to QFly and has a history of strong state government supported QFly management that has been significantly reduced since mid-2013. The citrus industry drives the recently introduced QFly management initiative. There are around 420 citrus growers in the region. One focus group and twenty interviews were carried out in March 2014.

##### *Young-Harden, New South Wales*

This case was chosen because local government is a key player in assisting forty local growers in a recently initiated effort to achieve area-wide management. QFly is increasingly a market access barrier to lucrative overseas markets, especially for cherry growers. One focus group and nine interviews were carried out in September 2013.

The design principles, which are summarised in Box 2, facilitate overcoming the social dilemmas of ‘opting out’ and free-riding as they create the conditions required to sustain the trust and reciprocity that is needed to sustain collective action. In addition, the principles are used as a diagnostic tool to deepen understanding about what social and institutional factors contribute to or hinder the success of industry-driven area-wide management (Cox et al. 2010). The hypothesis is that the most successful case study, i.e. Central Burnett, will align closer to Ostrom’s design principles than the Riverina and Young-Harden.

**Box 2. A summary of the design principles for robust common-pool resource institutions** (Ostrom 1990; Anderies et al. 2004; Cox et al. 2010; Poteete et al. 2010)

*a. Clearly defined boundaries*

The resource system’s boundaries and the individuals who have rights to use the resource and need to contribute to its maintenance, are clearly articulated. This underpins the development and enforcement of rules.

*b. Congruence between appropriation and provision rules and local conditions*

The rules in play that allocate benefits to different participants are fair and equitable, that is, they ensure the benefits individuals derive from the resource are in proportion to the contributions they provide. Rules also conform to local resource conditions, such as fluctuations over time and space. If rules are seen as fair there is less chance that resource users will challenge or violate them.

*c. Collective choice arrangements*

Individuals affected by the rules have a say in their design and modification. This ensures greater support for the rules; rules are better understood, are more likely to fit local circumstances, norms and values, and are adjusted when needed. It provides locals with the opportunity to experiment and fine-tune rules over time.

*d. Monitoring*

The condition of the resource is regularly monitored as well as risk contributors’ compliance with the system’s rules. Monitoring is done in a way that complements trust and reciprocity, rather than causing antagonism.

*e. Graduated sanctions*

Users who do not abide by rules first receive a signal that their breach has been noticed followed by more onerous consequences if the breach continues. Such an approach makes allowance for exceptional circumstances, misunderstandings

or mistakes and focuses on encouraging the violator to resume compliance. It is also important for other participants to witness that rule breaches are followed up, to maintain trust in the system.

*f. Conflict resolution mechanisms*

Participants and officials have ready access to low-cost, local arenas to address conflicts between stakeholders and to get it resolved quickly with minimal impact on the trust between participants.

*g. Minimal recognition of rights to organise*

The rights of participants to develop their own rules are recognised and supported by external authorities, such as local or state governments, thereby contributing to the legitimacy and enforceability of these rules.

*h. Nested enterprises*

Where the resource is part of a larger scale system, institutions are developed in a nested approach, where different layers complement each other. Smaller units adapt rules to local circumstances and larger-scale institutions regulate the interdependencies between smaller units and address larger-scale issues.

Ostrom's design principles seemed suited for on-ground pest management, because they focus on both the local social and institutional processes as well as on how these are nested in and interact with higher hierarchical levels of governance (Armitage 2007; Ostrom 2007; Poteete et al. 2010). Of particular interest here is the wider political and economic setting of national and international trade in which area-wide management programs are embedded, including the role of the state. However, due to space restrictions, this paper will highlight only some key elements.

A qualitative research approach was chosen to achieve in-depth understanding of the processes occurring at local level (Denzin and Lincoln 2000). Case studies were selected using theoretical sampling as opposed to random sampling. That is, cases were chosen to maximise gaining insight (Flyvbjerg 2006; Eisenhardt and Graebner 2007) about the social and institutional aspects of area-wide management programs. Hence, cases were chosen to achieve maximum variation of social and institutional profiles (Flyvbjerg 2006). Cases that involve existing or coordinated attempts to achieve industry-driven fruit fly area-wide management programs were considered.

The main data source is face-to-face, in-depth, semi-structured interviews with key informants as well as a focus group with each case study's management committee. Purposive sampling were used to select interviewees, i.e. people were chosen based on their knowledge, position or characteristics (Morse et al. 2008), such as how well they know how growers and/or the broader

community respond to the area-wide fruit fly management program. A range of interviewees were chosen to ensure a diverse range of perspectives (Eisenhardt and Graebner 2007). Key informants typically included local program coordinators, key growers, on-farm consultants, as well as representatives of the programs' management committees, packhouses, local shire councils and local industry bodies and associations. Interview questions during the fieldwork were broad and open-ended in order to obtain an authentic representation of how respondents view the local area-wide management program 'from the inside' (Punch 2005). Interviews typically went for an hour, were audio-recorded and transcribed verbatim. Data was coded using the qualitative research analysis tool NVivo. A summary of each case study's key findings was distributed amongst the cases' participants. They were asked to identify gaps or provide other viewpoints to documented findings, which led to a few more updates to the results.

## 4. Results

This section provides a more detailed overview of each case study, followed by jointly applying Ostrom's design principles across the cases.

### 4.1. Central Burnett

The area-wide management program started in 2003 as a trial led by the Queensland government in collaboration with three local crop consultants to strengthen fruit fly control and improve market access opportunities (Lloyd et al. 2010). In the past there were some peak trap catches of 240 flies/trap/day, which were dramatically reduced to 1 fly/trap/day by 2010. Likewise, backyard fruit infestation levels in towns dropped from 60.8% to 21.8% (Fay et al. 2011).

Area-wide management builds on a successful integrated pest management (IPM) program implemented by the crop consultants. IPM had already significantly reduced QFly pressure before area-wide management started (Lloyd et al. 2010). The state department for agriculture has carried out a number of QFly-related research activities in the region since the 1990s. Hence, local fruit fly activity was well understood and provided important baseline data for area-wide management (Lloyd 2007). It also resulted in an amicable and trust-based relationship between growers, the consultants and state government staff. The crop consultants have serviced around 90% of growers for twenty years or more.

Growers make voluntary contributions to fund QFly treatments in towns. Over the years the number of contributing growers has reduced considerably, with the most frequently mentioned reason for opting-out being that other growers do not contribute, yet still enjoy the same benefits. This was followed by disappointment that the program has failed to deliver the anticipated market access.

Between 1999 and 2007, Central Burnett was able to secure access to a number of domestic markets, without the need for post-harvest treatments, through the establishment of protocol ICA-28 Pre-Harvest Bait Spraying and Inspection of



Citrus (Fay et al. 2011). However, access to international markets without the need for costly cold sterilisation has not yet been obtained.

## 4.2. Riverina, New South Wales

This area presents a socially challenging case to achieving area-wide management, despite being traditionally not endemic to QFly. The key drivers for QFly management are to reduce pest numbers, prevent post-harvest treatments and to minimise impacts on market access opportunities (Davidson and Davidson 2012). The citrus industry is the main horticulture group pursuing coordinated QFly management. The region used to be part of the Fruit Fly Exclusion Zone (FFEZ), a formal interstate trade zone involving prevention and eradication activities co-funded and managed by state governments and industries (Voullaire and Dominiak 2003; Dominiak et al. 2006). However, New South Wales Department of Primary Industries (NSW DPI) abolished its on-ground operations after unprecedented QFly detections left the NSW FFEZ unviable (NSW DPI 2015).

The local management committee, Riverina Biosecurity, started in September 2012 to oversee biosecurity issues across all horticulture industries in the Riverina, using QFly as a starting point. This follows the demise of Riverina Citrus in 2012, a grower-funded local industry body which had a large involvement in regional QFly management.

## 4.3. Young-Harden, New South Wales

In September 2012, horticulture growers and local government started a local management committee called the Fruit Fly Action Group to address the challenge of QFly, as the pest increasingly impedes market access. The group is grower-driven and includes representatives from two shire councils, an on-farm consultant from a chemical company and a NSW DPI representative.

Intermittent QFly management and research activities by the state and local government have occurred in the region. For example, between 2003 and 2006, state government research revealed a strong case for the possibility of developing a QFly-related protocol for cherry market access, such as an area of low pest prevalence (Marte 2007).

Respondents report that QFly breeding in town backyards is a major concern. Some mentioned an increase in derelict orchards, lifestyle blocks and absentee landholders on land that used to be commercial orchards. Some exiting growers sold their land as a number of lifestyle blocks to maximise their capital gain.

## 4.4. Applying the design principles

### a. *Clearly defined boundaries*

In Central Burnett, the geographical boundaries of the area-wide management program lies within the North Burnett Region local government area. It includes all commercial horticulture operations, including predominantly citrus (mainly



mandarines), and some table grape and mangoes, reportedly involving around 60 commercial growers. The area includes the towns of Gayndah and Mundubbera, and a production area of around 2000 ha along the Burnett River (Fay et al. 2011). Signs have recently been erected along major roads in the region to discourage travellers from bringing fresh produce into the region.

Strong on-farm support for QFly management results from the majority of growers being export-focused or else supplying to QFly-sensitive domestic markets. Being located within the endemic QFly region, growers are well aware that on-farm QFly management is imperative. Having relatively small towns, means that town residents – who generally have less incentive to invest in backyard QFly management – can be dealt with as an externality. This makes it achievable for growers to fund regular backyard QFly management.

The Riverina covers the local government areas of Carrathool, Griffith, Leeton, Murrumbidgee, and Narrandera (Davidson and Davidson 2012). Varying levels of incentives to control QFly complicates securing support from all people with host plants on their land, even amongst the estimated 420 citrus growers. Most are part-time growers who run low-input production systems focused on the juice market. A smaller proportion of growers supplies to the export market. At the time of the fieldwork juice companies carried-out fruit inspections on arrival for signs of QFly infestation. For export-oriented growers, to achieve access to lucrative overseas markets without applying costly, postharvest cold sterilisation, regular monitoring of an extensive QFly trap grid across the region is required to supply hard evidence of low QFly prevalence. There are also several other horticultural industries, that, despite being declared hosts, are not economically affected by QFly. Likewise, many town residents and lifestyle landholders have little incentive to control QFly. Road signs to discourage travellers from bringing fresh produce into the Riverina were still in place from the FFEZ period. The Riverina Biosecurity was negotiating with NSW DPI to retain at least some of the signage.

The Young-Harden geographical boundaries include the two shire regions of Young and Harden. Setting achievable boundaries around who needs to comply with certain recommended practices is complicated through the varying levels of incentives, especially as many peri-urban landholders and town residents have little direct incentive to actively address QFly concerns.

b. *Congruence between appropriation and provision rules and local conditions*  
Naturally, Central Burnett growers' on-farm QFly investment is related to the size of their operations. In addition, the voluntary contribution that the management committee requests from each commercial grower to fund town treatments is based on the number of hectares that each grower has under horticulture production. In order to maximise the cost-effectiveness of QFly management, the frequency of QFly baiting depends on the crop under production and time of harvest. Citrus growers increase to weekly baiting from January to harvest (around August)

whereas mango and stonefruit growers apply baiting between half fruit growth to harvest (Lloyd 2007). Control is further intensified if QFly catches in monitoring traps increase above certain thresholds.

In the Riverina, export citrus growers would benefit most from successful area-wide management. Apart from already implementing onerous QFly management programs on-farm, one export grower mentioned that he is willing to spray for his neighbours if area-wide management would eliminate the need for costly cold sterilisation. However, there is no incentive for growers like him to invest in a much challenged area-wide management initiative beyond rigorous on-farm practices while they still have to invest in cold sterilisation.

Likewise, most export-oriented Young-Harden growers are reported as generally applying rigorous QFly management on-farm; yet there is little evidence of those benefiting most contributing most to this recently-initiated program. The local government tries to get the best output for input by applying bait sprays in towns during two periods per year when QFly numbers spike.

### *c. Collective choice arrangements*

The Central Burnett pilot program was co-funded by growers and a grant from the national research and development body, Horticulture Australia Limited. Growers, crop consultants and the state department research staff set the research agenda for the area-wide management pilot program, thereby responding to growers' self-identified needs. The management committee, called the Central Burnett Area-Wide Management Committee was formed in 2003. Until today it comprises the three crop consultants, citrus and non-citrus grower representatives, staff from the state government department for agriculture, a local shire council representative and a few other stakeholders (Lloyd et al. 2010). Growers tested new technologies such as male annihilation on-farm with the support of crop consultants and participated in an evaluation at the end of the pilot program. A grower survey carried out in 2005 showed one hundred per cent of growers were in favour of continuing the program (Lloyd 2007). As many growers employ a crop consultant, who serves on the management committee, most growers continue to have ample opportunity for two-way discussions with key decision-makers.

Extensive engagement with Central Burnett town residents commenced six months before the pilot program. Public meetings were held with the local crop consultants who explained the importance of, and the science behind, area-wide management. These interactions gave residents an opportunity to respond if they had concerns or questions. Residents were asked to give permission for QFly management activities to be carried out in their backyards on a regular basis. Key messages were reinforced with the distribution of flyers and posters through local shops. Respondents talked about town people remarking that they can now enjoy maggot-free backyard produce. At the end of the pilot program, 89% of residents supported the program (Lloyd 2007) and respondents reported that support remains high.

In the Riverina, no strongly established communication channels exists between Riverina Biosecurity and all horticulture growers in the region. Some horticultural industries have no local representative bodies, which complicates communication with these growers. Generally speaking, grower meeting attendance is low. Solidarity amongst citrus growers has also been damaged following a troubled past involving the demise of Riverina Citrus.

Communication with town people in the Riverina involves predominantly one-way communication, requesting town residents to maintain pest-free backyard hosts, this being done by media releases and radio talks. A number of workshops were planned to demonstrate to town residents and growers how to best manage QFly.

Young-Harden respondents mentioned that commercial growers are well-connected with each other, including connections with those serving on the Fruit Fly Action Group. However, connections with newer horticulture groups, such as a local Lebanese community, are weaker. Some growers on the Fruit Fly Action Group have amicable relationships and informally engage with Lebanese growers about the importance of QFly management, contributing to trust and communication channels between them.

Current communication with Young-Harden town residents, including two public meetings and various media releases, involves mainly one-way promotion of maintaining pest-free backyard hosts.

#### *d. Monitoring*

Monitoring of on-farm practices in Central Burnett happens when crop consultants visit farms. Crop consultants provide the management committee with up-to-date information on seasonal QFly activity, incidence of crop infestation, and the level of adoption of recommended practices.

Good financial record management ensures the management committee knows who contributes to the town treatments and who has ceased paying the levy. The reduced contributions has forced less intense town QFly treatments and monitoring. The management committee keeps a close eye on the effectiveness of the revised procedures to ensure QFly is still satisfactorily managed.

QFly prevalence in the Riverina is monitored through traps on growers' properties, in towns and other rural areas. Riverina Biosecurity has had some success with encouraging packhouses to insist on proof of QFly management from growers. Legislation requires Riverina residents to maintain QFly-free hosts. According to the Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order No. 45, 2011 under the Plant Diseases Act 1924, owners and occupiers of land or premises in the Riverina area are required to treat citrus and prune plants for QFly using specified bait sprays and to maintain a treatment record. Many interviewees expressed frustration that the state government does not enforce this legislation, several ascribing it to a lack of state government resources. A state government representative pointed to a moral constraint



preventing them from fining ordinary citizens for not maintaining fruit trees if they lacked resources or were not able-bodied, such as retirees. Enforced regulation requiring regular backyard maintenance might also be unpopular with voters.

Most Young-Harden growers monitor QFly pressure on-farm. The Young and Harden shire councils conduct monitoring in towns through a number of traps. NSW DPI also conducts some trapping in the region.

*e. Graduated sanctions*

There was no evidence of formal graduated sanctions for non-compliance with recommended QFly management practice in any of the case studies. In Central Burnett such growers might get a personal word from a crop consultant. Soft sanctioning is applied to Central Burnett growers who do not contribute to town treatments. They are indirectly identified by publically listing and thanking contributors in newspapers and providing them with gate signs. This has reportedly led to some growers resuming their contributions. One respondent called it a 'blame and shame system in disguise' and said that if the management committee was authentic about thanking contributors, they should have done it from the start.

*f. Conflict resolution mechanisms*

No formal conflict resolution mechanisms were identified in any of the case studies. The management committees would be the first point of call to resolve QFly-related conflict.

*g. Minimal recognition of rights to organise*

Government agencies across state and federal levels are supportive of all three case studies to organise themselves to achieve and maintain area-wide management.

*h. Nested enterprises*

The pilot Central Burnett area-wide management program and the research leading up to it are evident of complementary nested systems. This is how a crop consultant described it:

*[We used to have the Central Burnett Horticultural Committee. Growers were paying a levy for regional R&D and marketing. We had two meetings a year. [Two specific QDPI&F staff] would come along, we would say we have problem with this, they'd say we will apply with HAL if you contribute. And then we got involved in the fruit fly stuff. The project was driven by [the three crop consultants]. This is the issues we found, we would call on DPI [state government Department of Primary Industries] people and they come up with project and get on with it.]*

Nowadays, the Queensland state government still provides some support through representation on the management committee and identifying insects caught in

traps. However, a lack of resources was mentioned as a barrier to receiving further government support.

Despite spectacular QFly management in Central Burnett, area-wide management has failed to translate into formally supporting international market access without the need for cold sterilisation. Attaining international market access is a complicated, sometimes politicised process and growers are to a great extent dependent on government representatives and industry bodies to pave the way and provide needed support. The reduction in growers making voluntary contributions to the town treatments partly results from disappointing market access outcomes. A grower no longer supporting town treatments explained it as follows:

*'The concept is correct by lowering the general fruit fly population in the whole district ...The goals were correct at the start for market access, that is what it could do for getting access to Victoria, South Australia and internationally. But in reality we have been showing good results for five to six years now and still we need to cold treat for export. New markets all require cold disinfestation too. So, it [area-wide management] is not paying back. It misses the mark in what they said it would do. For us to fund it [the town treatments] without seeing any real benefits...we are already spending lots of money on fruit fly management [on-farm], including MAT, baiting and cover sprays if we need to.'*

The NSW state government and the peak industry body, Citrus Australia, provide support to the Riverina initiative through their involvement in Riverina Biosecurity. However, there was little devolution of power beyond state government, such as enforcement powers, to back-up softer engagement activities with people who have little incentive to manage QFly on their properties.

In Young-Harden, the NSW state government also provides valuable input, although respondents were disappointed with the difficulty of securing support from the NSW Minister responsible for agriculture. Respondents were also frustrated with a lack of feedback from the Australian Department of Agriculture – as the responsible body for international market access negotiations – about what is required on-farm to achieve access to certain markets. Some respondents suggested that the Australian Government does not appreciate the cost of impractical on-farm requirements that are the result of government-to-government negotiations. As with the Riverina, there was little devolution of power beyond state government, to bolster the softer engagement activities with town residents. Local government was investigating what it could do within its powers, such as requiring removal of trees or a management plan for fruit trees when land is sold.

## 5. Discussion

This section provides a synthesis of the main lessons learned from applying Ostrom's design principles to area-wide management of QFly. In terms of the need for clearly defined boundaries (principle 1), geographical boundaries are overall

well-demarcated. However, these boundaries are porous, especially in areas that are located on major travelling routes, as travellers can bring QFly-infected fruit into the regions. In the Central Burnett and Riverina cases management committees use road signs to discourage travellers from bringing fresh produce into the region.

Most challenging here, due to the varying incentive levels for QFly management, is determining who needs to implement QFly management strategies, what is required from them and how to secure their commitment. In the Riverina and Young-Harden this is complicated due to the heterogeneity amongst risk contributors. Even within the Riverina citrus industry, most growers would in principle agree that collective QFly management has value, but the different market requirements imposed on them (e.g. juice versus export growers) complicates finding a shared vision for QFly management. In addition, many part-time growers have other sources of income. Cox et al. (2010) point out that the dependence of risk contributors on a resource is directly related to the incentive they have to support cooperative behaviour. The findings suggest that collective action is easier to achieve when horticulture growers have fairly homogenous on-farm objectives, such as in Central Burnett. To address QFly risk from non-commercial land, the Central Burnett shows that small town communities are helpful as it is more feasible to implement QFly management for them.

Although there is some ambiguity in literature about the impact of heterogeneity, generally speaking, it is seen as presenting challenges to collective action (Ostrom 2010). Heterogeneity complicates achieving proportional equivalence between benefits and costs, i.e. congruence between appropriation and provision rules (principle 2). When participants' investments are not proportionate to the distribution of eventual benefits, incentives for cooperation is diminished. This challenges decision-making (Valentinov 2007) and adds to the transaction cost of achieving consensus (Ostrom 2010; Chaddad and Iliopoulos 2013). It affects whether locals perceive rules as fair, an important condition for gaining support for local institutions. Identifying who is gaining from biosecurity measures, to what extent and therefore who ought to contribute most, is not always evident (Donaldson 2013). For example, the ratio of who benefits most from area-wide management depends on whether the scheme is accepted by international markets to the point that it makes post-harvest treatments, such as cold sterilisation, obsolete. The willingness of a Riverina export grower to undertake some QFly management activities on his neighbours' land if area-wide management eliminate the need for cold sterilisation confirms findings elsewhere. That is, wealthy members sometimes accept a disproportionate economic responsibility to ensure the success of collective action provided the benefit they gain from it justifies their actions (Jones 2004).

If the number of risk contributors who have little to benefit from QFly management greatly outweighs the number of main beneficiaries – usually full-time, commercial growers – it is not feasible for these growers to pick-up the cost of QFly management for other risk contributors. For example, in Central Burnett



there are around 60 growers keen to export. The towns are relatively small with Gayndah having 1789 residents and Munduberra 1042 residents in 2011 (ABS 2015). In the Riverina, by contrast, growers focused on the export market form a minority of the total of 420 citrus growers. This area includes the large regional centre of Griffith with a population of 17,616 residents in 2011, as well as Leeton with 8414 residents and Hillston with 1430 residents (ABS 2015).

There was also evidence of congruence of appropriation and provision rules with local social and environmental conditions, the second part of principle 2 (Cox et al. 2010). In all case studies those involved in QFly management intensified control activities at certain times of the year in conjunction with times of peak QFly pressure, or when the pest can cause most damage. The deployment of traps to monitor of QFly pressure plays a key role here.

Finding and implementing ways where most of those affected by the local institutions have their views represented can be challenging (principle 3 – collective choice arrangements). As demonstrated in the case studies, relationships play a facilitating role. Informal relationships between commercial growers in Young-Harden assist in two-way discussions between those who are on the management committee and others affected by the group's decisions. In Central Burnett, engagement with those affected by decisions happens in a number of ways. First, the area-wide management program was developed in a participatory fashion with significant input and involvement of growers. Hence, the program was designed in a way that was appropriate for local socio-economic, cultural and political contexts (Pretty 1995; Gonsalves 2005). Second, existing relationships between growers and crop consultants imply strong ties between growers and the management committee. The transaction cost to achieve similar engagement in, for example, the Riverina, would be much higher as the grower population is far bigger, more fragmented, and there is less evidence of an existing effective 'communication infrastructure'. Collective choice arrangements also mean that management committees need to enjoy legitimacy and credibility with different local groups in order to influence their behaviour. This is again obscured in the Riverina, due to fragmentation resulting from the large variety of horticulture industries and tension within the citrus industry relating to the demise of Riverina Citrus. This implies that Riverina Biosecurity as a start might benefit from greater representation across different sections within the local citrus industry to consolidate industry support, as opposed to the current high representation of external bodies.

The fact that Central Burnett town residents receive 'free' QFly management makes it unsurprising that such a high percentage support the program. In contrast, town residents are more likely to feel QFly requirements are imposed on them when they are being asked to purchase treatments and invest time and effort indefinitely to maintain their fruit trees. The true cost of effective community and grower engagement to underpin collective choice arrangement can be easily underestimated. Pest management presents the added challenge that when control activities are most cost-effective, i.e. when the pest is not present yet or at very

low numbers, it is difficult to secure interest from stakeholders, such as town residents and even local government. This has been the past experience in the Young-Harden case study.

The importance of monitoring (principle 4) has been described in the area-wide management literature (Vreysen et al. 2007a). Monitoring of QFly pressure was evident in all case studies, with varying numbers of traps under surveillance on-farm and in towns. Sharing and collating data from different traps can assist in developing a clearer picture of QFly behaviour across the region. However, some respondents reported that information generated by state government traps did not reach all interested parties.

More challenging is monitoring people's compliance with recommended practice. The case studies reveal a number of ways of using existing channels that could be helpful. In Central Burnett, the crop consultants' visits to farms give a good insight into compliance levels. In the Riverina, some packhouses insist on proof of QFly management. Some believed that other reluctant packhouses might follow suit if QFly pressure increased and started to affect their supply. State government-issued legislation that enforces compliance was complicated for a number of reasons. The Treatment and Eradication of Queensland Fruit Fly Order in the Riverina requires QFly host owners to implement pest management strategies. However, enforcement is thwarted by a lack of resources for consistent compliance monitoring. NSW DPI representative also pointed out that a heavy-handed approach of imposing fines on non-complying residents poses a moral dilemma, especially when people have limited ability to comply. This also conflicts with the need for implementing graduated sanctions.

Overall there was limited evidence of graduated sanctions (principle 5). Dyck et al. (2005), in their review of area-wide management programs involving the sterile insect technique, recommend that penalties for poor performance need to be negotiated before the program commences. These requirements should form part of an official agreement between stakeholders, rather than an agreement between friends. In Central Burnett, the indirect tactic to publicly thank contributing growers and thereby expose non-contributors had some success in gaining renewed commitment from some to support the town treatments. This system represents a second-order reward or a positive sanction, where those who are cooperating are rewarded in order to provide an incentive for defectors to also cooperate. Rewards work better than punishment as they increase the average payoff for the group, whereas punishment lowers the average payoff for the group (Kiyonari and Barclay 2008). However, as this tactic was not built into the program early-on there is a risk that violators will perceive it as a punishment, as the feedback from one respondent reflects.

Support from state government agencies and peak industry bodies go some way in meeting the principle of nested enterprises (principle 8). However, it seems that with international market access the nested approach become unstuck. Market integration can impede successful collective action due to its influence on local incentive structures and power relations (Cox et al. 2010). Findings from



the case studies suggest that abiding by national and international trade rules represents a 'top-down' element to on-ground QFly management strategies. For example, trade protocols provide detailed requirements to manage pest risks on-farm and throughout the supply chain. Several growers lamented that protocols by importing countries sometimes present impractical and not necessarily effective ways to prevent pest infestation, but they need to abide by them in order to be permitted to access export markets. This can interfere with adaptive management on the ground, i.e. the inclusive process where key stakeholders, including growers and researchers, learn from doing in their own context, rather than mere implementing management activities (Allan and Curtis 2005; Folke 2007; Berkes 2010).

In the area of pest management for market access the state plays many institutional roles that widen the power differential between the state and growers. As regulator, the state increasingly shapes national and state biosecurity policies to reflect international trade regulations, such as those set by the WTO, rather than solely basing policies on the needs of growers (Wisseman et al. 2003). The state enforces many of the national and international trade requirements, including inspections, auditing and accreditations. However, it is also a partner in assisting growers to overcome pest issues; for example, by providing resources for research and on-ground activities, advice about the technical aspects of QFly management and market access requirements.

Unsurprisingly, many respondents mentioned that government needed to play an enabling role in achieving industry-driven area-wide management. In particular, respondents want government to actively promote area-wide management as a suitable phytosanitary measure as part of a systems approach during market access negotiations, in order to overcome the need for cold sterilisation. Industry representatives are not allowed to participate in negotiations between importing and exporting countries' governments, so respondents saw it as government's role to champion area-wide management. However, market access experts explained that, despite formal allowance in the ISPMs for systems approaches, in reality these are problematic. In particular, demonstrating the combined efficacy of different QFly management techniques throughout the supply chain is difficult. Markets therefore continue to show preference for 'one kill step' measures, such as cold sterilisation, or previously, the now restricted chemicals.

Other government roles and actions that were mentioned as being helpful in the context of QFly management included enforcing compliance with QFly management practices; advice about how to strengthen market access opportunities; establishing network opportunities with different government departments and groups; overcoming regulatory challenges and 'red tape'; and negotiations with other government departments on issues such as erecting road signs. Factors mentioned that hamper progress on the ground included high government staff turnover, slow government processes, the difficulty of reaching the right government official to talk to and apathy to grower needs, such as government officials who may attend meetings but are not truly engaged.

This work shows that, unlike the age-old concept of pest control, the concept of biosecurity and the related national and international plant protection institutional frameworks are attached to certain worldviews (Donaldson and Wood 2004). These are embedded in paradigms of neoliberalism, the dominance of market forces, standardisation (Dibden et al. 2011) and heavy reliance on scientific expertise. It involves the belief that processes of categorisation, ordering and accompanying rules can stem the flow of unwanted organisms from ‘unclean’ infested areas to ‘clean(er)’ controlled areas and provide assurances that produce is free of unwanted organisms. In particular, control of human behaviour is seen as the key mechanism to achieve desired outcomes (Donaldson and Wood 2004) in a realm that, in practice involves a complex interplay between the environment, host plants, humans and the problematic organism, here QFly (Hinchliffe et al. 2013). Although this status-quo clearly has weaknesses and is increasingly critiqued (Donaldson and Wood 2004; Dibden et al. 2011; Hinchliffe et al. 2013), for commercial horticulture growers these are the realities that they need to deal with in order to maintain their livelihoods. Moreover, in the worldview of those who do not need to respond to these national and international institutions, QFly present a mere nuisance, the level of which is related to how much they value their home-grown produce. In the context of the commons, this discord between worldviews is likely to challenge the ability to achieve collective action.

## 6. Conclusion

The case studies illustrate that there are no ‘one size fits all’ local institutions that will be ideal for all area-wide management programs (Carlsson and Sandström 2007). There are certain traits of commercial pest management that shape the abilities of ventures such as area-wide management to align with the design principles. First, these initiatives can involve a large number of risk contributors who have little incentive to manage the pest. Second, there is a large power differential between growers and the state as international and national biosecurity institutions present top-down elements to pest control for market access. Growers are to a great extent dependent on state negotiations with prospective importing countries or states to achieve market access. If anticipated market access fails, local support for all aspects of an area-wide management program is likely to decline. Three, the onerous requirements set by international biosecurity institutions and QFly-sensitive markets contribute to more heterogeneous objectives amongst growers about what a regional QFly management program should involve.

Apart from certain biophysical traits within a region, the social profile of local industries and town communities play a key role in achieving compliance with the Ostrom design principles. In Central Burnett, the long-term presence of the three crop consultants, a relatively homogenous industry, small sympathetic towns and a participatory research-based lead-up to the program, are major contributing factors to the success of this area-wide program. The Riverina and Young-Harden are challenged by the heterogeneous incentives for the different landholders who

range from full-time commercial growers to lifestyle and absentee landholders and town residents. These findings suggest that industry-driven area-wide management will be hampered in regions where different types of landholders co-exist.

There is a key message from this work to horticultural industries contemplating industry-driven area-wide management. Despite the fact that the QFly management technologies developed in successful cases such as Central Burnett provide a great exemplar for other areas, disconnecting them from the socio-institutional context in which they emerged, is likely to result in unrealistic expectations elsewhere.

This study demonstrates that the commons can make a significant contribution to gaining insight into maintaining sustainable agriculture. It also confirms the finding of Agrawal (2001), that there is a need to investigate the impact of markets on the commons and how to apply socio-ecological systems thinking in a market-based environment.

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## **4.2 Article 2. Adaptive co-management for collaborative commercial pest management: the case of industry-driven fruit fly area-wide management**

Adaptive co-management provides a pragmatic way for local industries to initiate local collective fruit fly management initiatives. Key principles contained in the adaptive co-management literature are used as a lens through which the case study findings are explored to better understand what enables AWM.



## Adaptive co-management for collaborative commercial pest management: the case of industry-driven fruit fly area-wide management

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### ABSTRACT

Area-wide management is recommended for managing several mobile pests. With limited on-ground government assistance available, several Australian local industry groups drive such initiatives to minimise Queensland Fruit Fly impacts on production and market access. This qualitative study investigates how adaptive co-management thinking can assist industry-driven area-wide management. The concepts of social learning, communication, adaptive capacity, shared decision-making and shared authority can make valuable contributions to strengthening collaborative pest management. The tension between "top-down" market requirements and "bottom-up" adaptive co-management principles is best addressed if local industries focus primarily on minimising pest infestation and view market requirements as a bolt-on component.

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Fruit fly; adaptive co-management; area-wide management; social learning; collaboration; market access

### 1. Introduction

When reliance on main pesticides is curbed by new restrictions and on-ground government support for pest control is dwindling, growers are in need of innovative pest management strategies. This is the challenge that many Australian horticulture growers face in relation to the pest Queensland Fruit Fly (*Bactrocera tryoni* (Froggatt)), or in short, QFly.

In the environmental sciences, adaptive co-management is a valuable approach to managing socio-ecological systems when uncertainty and complexity are high (Olsson et al. 2004; Charles 2007). Armitage, Plummer, et al. (2008, p. 96) define adaptive co-management as "a flexible system of resource management, tailored to specific places and situations, supported by, and working in conjunction with, various organizations at different scales." Evidence of adaptive co-management thinking being applied to regional pest management is scant, especially in the context of supporting market access.

Local Australian horticulture industries are recommended to manage QFly on a long-term, area-wide basis (PHA 2008; Plant Biosecurity CRC 2015). Area-wide management (AWM) involves synchronised pest management implemented across a geographical area, often including non-commercial land and urban settings where the pest can reproduce (Vreysen et al. 2007).

This research article describes how adaptive co-management principles can assist in strengthening industry-driven fruit fly area-wide management

(FF AWM) programmes. It extends the adaptive co-management literature to include considerations for commercial agriculture and in particular, managing biosecurity risks. This is timely as prevailing neoliberal paradigms and limited state budgets in several countries increasingly push local industries to be more self-reliant and less dependent on direct government support (Cheshire & Lawrence 2005).

#### 1.1. QFly

QFly is one of Australia's most destructive horticultural pests (Clarke et al. 2011). Many crops of Australia's almost AU\$9 billion horticulture industry (ABS 2014) are susceptible to varying degrees (Plant Biosecurity CRC 2015).

The dynamics of QFly vary between regions depending on the local geography, the host range, the availability of moisture, temperature and the likelihood of infested fruit entering the region (Dominiak et al. 2006; Clarke et al. 2011). Recent years involved wet warm seasons in eastern Australia, resulting in expanded QFly populations (Dominiak & Ekman 2013). The vulnerability of horticulture industries to QFly in Australia's southern states is forecasted to increase due to climate change (Sutherst et al. 2000).

#### 1.2. The institutional context of QFly

The institutional context of QFly adds further layers of complexity and uncertainty to dealing with this pest.



Several state governments have reduced on-ground support for QFly management (for example, NSW DPI 2012), forcing local industries to be more self-reliant. Restrictions have recently been placed on two key pesticides, fenthion and dimethoate, which have traditionally been used to control the pest at low cost through a simple single-treatment approach (Dominiak & Ekman 2013).

A key concern of QFly is that it can restrict market access, even if production impacts are negligible. A strong export market is important for all growers of a particular industry by preventing oversupply in the domestic market. As QFly is unique to eastern Australia and some South Pacific islands (Clarke et al. 2011), importing countries can restrict trade or demand phytosanitary measures under World Trade Organisation (WTO) trade rules (Potter 2013). Although such measures benefit growers by enabling trade, they can impose significant cost as illustrated in Box 1. Finding less costly alternatives is a top priority to horticulture industries. There are non-protocol countries, but they tend to be oversupplied offering lower returns. Due to Australia's high horticulture production costs, lucrative markets are important for many growers to remain profitable.

Internationally and nationally, there is pressure to harmonise phytosanitary measures (IPPC 2006; NFFS Implementation Committee 2009). Internationally, the

International Plant Protection Convention (IPPC) oversees the development of international standards for phytosanitary measures (ISPMs) that are accepted by the WTO to underpin trade. Likewise, Australia's domestic trade is underpinned by the interstate certification assurance (ICA) scheme involving various protocols to provide assurances to importing states that certain pest risks have been addressed following verifiable standard operating procedures, many relating to QFly. The QFly Code of Practice (CoP) is another example of harmonised pest management practices. The current Code (1997) is regarded as outdated partly because it does not make allowance for more recent measures such as maintaining areas of low pest prevalence that are typically underpinned by AWM. The Code contains detailed prescriptions, including the type of QFly monitoring traps required, their spacing specifications and thresholds for the number of flies caught per trap before corrective action is required.

In this context and following the restrictions on fenthion and dimethoate, a systems approach is seen as a suitable alternative approach to deal with QFly problems (PHA 2008; Dominiak & Ekman 2013), that is, applying two or more independent strategies that collectively ensure freedom from QFly in traded produce. An area of low pest prevalence is a promising strategy to be used in such approach (PHA 2008; Lloyd et al. 2010). International trade rules make allowance for such systems by providing broad guidance, including "ISPM 30 Establishment of areas of low pest prevalence for fruit flies" and "ISPM 35. Systems approach for pest risk management of fruit flies". However, the finer details for system approaches to underpin international market access are still being refined (APPPC 2015).

#### **Box 1. Examples of the consequences of cold treatment as a post-harvest QFly treatment**

- Cold treatment costs approximately AU\$115 per ton for growers in the Riverina region (personal communication, David Daniels, Citrus Australia, 15 January 2016), which represents a considerable part of income derived from this commodity. Growers received around \$1070 (2013), \$1150 (2014) and \$1260 (2015) per ton for export oranges (Fresh Intelligence Consulting 2016).
- Cherries from Young–Harden need 21 days of cold treatment to enter several protocol countries. Growers' preference would be for delivering produce to markets soon after harvest using airfreight as cold treatment can cause quality deterioration in cherries. The delay also undermines competitiveness, missing high-return periods when market supply from elsewhere is low and forfeiting opportunities to establish supply over a long seasonal window (personal communication, Hugh Molloy, Antico International, 12 January 2016).

#### **1.3. The need for adaptive co-management**

As implied earlier, pest control in agricultural systems traditionally involves a positivist technocratic mode of thinking, that is, reasoning is predominantly based on objective and absolute knowledge that is regarded as universal truths. Knowledge hierarchies exist that determine whose knowledge counts (Bickerstaff & Simmons 2004; Enticott & Wilkinson 2013). Communication with local grower and town communities often relies on top-down, generic information provision (Royce 2011). Although important, Enticott and Franklin (2009) warn that "expert" knowledge should not be privileged at the expense of local knowledge and learning processes rooted in the local socio-economic, cultural and political contexts. There is a need for a more constructivist approach, i.e. involving different knowledge systems to develop control strategies appropriate for the local context.

Adaptive co-management promises to overcome the constraints of reductionist approaches that gain



understanding of systems by understanding the smaller composing elements. Instead, adaptive co-management deals with uncertainty and complexity in a more holistic way within a particular context through an emphasis on continual learning by drawing on different knowledge systems (Olsson et al. 2004; Berkes 2007a; Armitage, Marschke, et al. 2008; Plummer & Hashimoto 2011). Literature presents many facets associated with adaptive co-management, including acknowledgement that it is neither a precise science nor an "all-or-nothing" approach (Charles 2007). Plummer and Armitage (2007) undertook a Delphi study with 30 adaptive co-management experts and identified five key inter-related components:

- Social learning – on-going, mutual learning between diverse stakeholders across scales drawing on different knowledge systems (Schusler et al. 2003; Lebel et al. 2006; Luks & Siebenhüner 2007). It includes "learning-by-doing" that assists in identifying context-specific ways to address issues in socio-ecological systems (Janssen & Anderies 2007; Leys & Vanday 2011).
- Communication – information flows between all partners and across scales, resulting in a shared understanding of issues, possible strategies (Plummer & Armitage 2007) and eventually working towards the same goals.
- Adaptive capacity – making adjustments in response to feedback, including the capability to design systems to withstand perturbations and adapt without losing key functionality (Folke et al. 2003; Armitage 2007).
- Shared decision-making – requires interactive participation of key stakeholders in setting priorities, formation of local institutions and other local decisions by building on multiple knowledge systems (Pretty 1995).
- Shared authority – power is shared between at least two stakeholder groups, usually but not always public and private groups (Plummer & Armitage 2007).

Adaptive co-management entails an iterative management process (Pahl-Wostl & Hare 2004; Leys & Vanday 2011) where knowledge development processes are closely linked to on-ground decision-making and implementation processes (Luks & Siebenhüner 2007).

## 2. Data and research design

### 2.1. Research overview

The research questions addressed in this article are

- How can adaptive co-management thinking assist industry-driven FF AWM?
- How can the lessons learned from the industry-driven FF AWM case studies advance adaptive

co-management theory, especially in relation to achieving market access?

The collective action and collaborative nature of AWM suggest that AWM lends itself well to adaptive co-management principles. However, there is a caveat as AWM is not an end in itself as there are other options to control QFly. In certain contexts, alternative approaches might be more appropriate, including farm-wide management or creating pest-free places of production. These options have limitations, and discussing them falls beyond this article's scope. Moreover, collective action has several challenges, most notably free-riding and people opting out when others are not following recommended practice (Ostrom 2005). Collaboration is further challenged by heterogeneity and high numbers of resource users. Kruger (2016) investigates these challenges for AWM and they are not addressed in detail here.

### 2.2. Methods

This qualitative investigation is based on three case studies of where AWM is either implemented or attempted. There are few established industry-driven FF AWM programmes in Australia; hence, recent initiatives were included to better understand the challenges involved in starting these programmes. Case studies provide a key strategy for studying a phenomenon in its natural setting by including both the complexity and the influence of context (Punch 2005). This project assumed early on that regions will differ significantly, which impacts their ability to achieve collective action (Ostrom 2005). Hence, theoretical sampling of case studies was used (Eisenhardt & Graebner 2007) to achieve maximum variation of social and institutional profiles (Flyvbjerg 2006), including different demographic profiles, histories and supporting parties.

Table 1 contains an overview of the case studies. This article puts particular focus on Central Burnett as the critical case study, as it is seen as a model of industry-driven QFly management (Davidson & Davidson 2012; Hargreaves & Nimmo 2012; PHA 2008). Although some believe that replicating the development of the Central Burnett programme is impractical (Clarke et al. 2011), understanding how success came about is important, including identifying lessons learned. The Riverina – as it operates now – and Young–Harden are recently established programmes, and although it is too early to tell whether they are successful, they have traits that are helpful in this analysis.

The main data sources were 43 in-depth, semi-structured interviews with key informants and three focus groups with management groups across the three case studies, which occurred between September 2013 and March 2014. Where available, existing reports and management group meeting minutes were also investigated. Key informants were selected using purposive



Table 1. Overview of the case studies.

	Central Burnett	Riverina	Young–Harden
Location and/or local government areas (LGAs)	Along the Burnett River within the North Burnett Region LGA	LGAs of Canathool; Griffith; Leeton; Murrumbidgee; Narrandera	LGAs of Young and Harden
No. of commercial growers (according to respondents)	60 (mainly citrus) <sup>a</sup>	Approx. 420 <sup>a</sup> citrus growers; 372 <sup>a</sup> grape growers; 55 <sup>a</sup> prune growers	Approx. 40 <sup>a</sup> stonefruit growers (most grow cherries); 20 <sup>a</sup> grape growers
Crops produced	2266 ha <sup>a</sup> citrus (mainly mandarins); 370 ha table grapes (Lloyd et al. 2010)	8133 ha <sup>a</sup> citrus; 7200 ha vegetables; 15,000 ha grapes (RDA 2014); 1365 ha walnuts; 885 ha prunes; 300 ha cherries; smaller plantings of other hosts (approx. 30,000 ha of horticulture) (Davidson & Davidson 2012)	Estimated 650–700 ha <sup>a</sup> cherries; and up to 1000 ha <sup>a</sup> of wine grapes
• Support for AWM	<ul style="list-style-type: none"> <li>• All growers implement rigorous QFly baiting</li> <li>• Growers fund town treatments, but contributions are dwindling</li> </ul>	<ul style="list-style-type: none"> <li>• The local citrus industry pushes for broad-scale QFly management to support market access</li> <li>• Other horticulture industries show little interest as QFly does not affect them economically</li> <li>• Too early to tell</li> </ul>	<ul style="list-style-type: none"> <li>• The push comes from the cherry industry to support market access opportunities</li> <li>• Grape growers are less engaged as QFly does not affect them economically</li> <li>• Too early to tell</li> </ul>
• Indicators of success	<ul style="list-style-type: none"> <li>• Successful QFly suppression in season</li> <li>• QFly management practices led to CA-28, increasing domestic market access</li> </ul>		
• Factors enabling AWM	<ul style="list-style-type: none"> <li>• Trust relationships between growers and crop consultants</li> <li>• Small compact industry – growers have similar objectives</li> <li>• Small, horticulture-dependent towns</li> </ul>	<ul style="list-style-type: none"> <li>• Low pest pressure</li> <li>• Cold winters</li> </ul>	<ul style="list-style-type: none"> <li>• Low pest pressure</li> <li>• Cold winters</li> <li>• Local government support</li> </ul>
• Factors hindering AWM	<ul style="list-style-type: none"> <li>• Lack of enforcement mechanism to sustain grower contributions for town treatments</li> <li>• QFly is endemic</li> </ul>	<ul style="list-style-type: none"> <li>• Large number of horticulture growers</li> <li>• Fragmentation – both across horticulture industries and within citrus industry, leading to multiple on-farm objectives</li> <li>• Lack of representative leadership</li> <li>• Many part-time, low-input citrus growers</li> <li>• Large towns dependent on multiple industries</li> <li>• Lack of local power to enforce cooperation</li> <li>• Lack of communication channels to all horticulture growers</li> </ul>	<ul style="list-style-type: none"> <li>• Medium-sized towns</li> <li>• Lack of local power to enforce cooperation</li> <li>• Lack of communication and influence across all horticulture growers in the region</li> </ul>

Note:

<sup>a</sup>Numbers provided by local industries.<sup>b</sup>Personal communication with Nathan Hancock, Citrus Australia Limited (12 February 2016).

sampling (Morse et al. 2008), i.e. respondents were chosen based on their current connection with the regional QFly issue. A range of respondents were chosen to ensure a diversity of perspectives (Eisenhardt & Graebner 2007). They were identified based on their official roles and their insight in the local situation as proposed by stakeholders. They included local programme coordinators, key growers, on-farm consultants as well as representatives of programmes' management groups, packhouses, local shire councils and local industry associations. Interview questions were broad and open-ended to allow for authentic accounts (Punch 2005). Respondents were asked about their experience with the programme, its progress and their perspectives on the local management group, communication processes used, how learning occurs and the contribution of different stakeholders. Interviews were audio-recorded and transcribed verbatim and then coded using the qualitative research analysis tool NVivo. A summary of the findings of each case study was sent to the particular case's respondents to identify gaps or to add additional perspectives. This

led to a few additional updates to the findings. Documented studies about the social aspects of FF AWM, in particular the Hawaii FF AWM programme (Mau et al. 2007), were also studied.

### 3. Findings

This section outlines each case study in light of aspects relevant to adaptive co-management. Table 1 provides a comparative overview of key traits of each case. Systems approach trials were initiated in both the Riverina and Young–Harden with the support of New South Wales Department of Primary Industries (NSW DPI) in 2015. As these developments occurred after the fieldwork, they are not covered in this paper.

#### 3.1. Central Burnett (Queensland)

QFly management in Central Burnett shows spectacular results. Peak trap catches before AWM were up to 240 flies/trap/day, but were reduced to 1 fly/trap/day



by 2010. Backyard fruit infestation levels in towns fell from 60.8% to 21.8% (Fay et al. 2011).

Current QFly management is the product of decades of refinement with incremental advances over time. A local private crop consultant became involved in the region in the late 1970s when integrated pest management was initiated to reduce dependence on chemical pest control. It led to the currently used QFly baiting and trapping practices. He was later joined by two other consultants, who initially worked for him but eventually became independent consultants, resulting in similar thinking about QFly control amongst them. Collectively, they have served around 90% of growers for over 20 years.

In the past, growers identified and co-funded QFly research projects through a local research and development levy-based body, the then Central Burnett Horticulture Committee, in conjunction with researchers from the then Queensland Department of Primary Industries (QDPI). The researchers drew on their knowledge gained from the earlier papaya fruit fly eradication in north Queensland. Research in the late 1990s proved that there was extremely low QFly infestation in commercial citrus during the winter season. This enabled a systems approach-based protocol (ICA-28) based on a "winter-window" underpinned by pre-harvest bait spraying and fruit inspection, which facilitated domestic market access to some Australian states (Lloyd et al. 2010).

When an AWM trial, co-funded between the then Horticulture Australia Limited and local growers, was introduced in 2003, local QFly behaviour was already well understood (Lloyd 2007). The Central Burnett Area-Wide Management Committee formed in 2002 and still comprises the three crop consultants, citrus and non-citrus grower representatives from grower groups, state government staff (although less involved than before), a local shire council representative and some other local stakeholders (Lloyd et al. 2010). Respondents emphasised that AWM continues because the management group drives it. Meeting minutes reflect regular activities to remind growers and town residents to support the programme.

Many research and implementation activities happened in growers' orchards. Crop consultants and QDPI researchers assisted growers to fine-tune systems to suit individual operations. Earlier research showed that towns provided hotspots for QFly breeding. During the AWM trial, the project budget funded town treatments, lowering QFly pressure coming from towns. These successes contributed to 75% of growers agreeing to contribute financially to the programme's continuation (Lloyd 2007). Town treatments are still funded with grower voluntary contributions.

Crop consultants are in regular contact with grower clients providing opportunity to discuss QFly-related issues. Consultants understand what is happening

across the region in terms of current on-farm practices, growers' opinions and the QFly situation. The AWM trial project team made additional efforts to strengthen communication and relationships with other local horticultural industries. Personal contact is complemented with other communications, including letters to growers, local newspaper articles, occasional radio talks and displays at community events (Lloyd 2007).

However, getting lucrative overseas markets to accept the AWM programme as a suitable phytosanitary measure has not been achieved. This is in part due to the on-going review of the QFly CoP (Fay et al. 2011). QFly-sensitive overseas markets require the region's produce to undergo cold treatment.

### 3.2. Riverina, New South Wales

Citrus is the main industry pushing for QFly control in this extensive, multi-crop area as it hinders market access, especially for export navels. Since July 2013, NSW DPI handed on-ground QFly control to local industry. The region used to be a part of the Fruit Fly Exclusion Zone (FFEZ), a formal interstate trade zone co-funded and managed by state governments and industries (Dominiak et al. 2006). NSW DPI withdrew support after unprecedented QFly detections left the NSW FFEZ unviable (NSW DPI 2012). Moreover, a local industry body, Riverina Citrus, ceased in 2012 due to local tension about its management. It played a key role in QFly management, such as working closely with NSW DPI and local governments to manage QFly in towns. Local councils' involvement in QFly management ceased when NSW DPI reduced its support. Respondents mentioned that town residents and growers now seem accustomed to others addressing QFly problems and lack ownership of the issue.

At present, NSW DPI support to industry includes assisting with market access applications, explaining market access regulations, offering technical information and checking a reduced trapping grid to monitor QFly levels.

Most citrus growers run low-input, part-time operations producing for the juice market. A smaller proportion is focused on lucrative, but QFly-sensitive, export markets and they are eager for the cold treatment requirement to become obsolete.

Against this backdrop, Riverina Biosecurity started in September 2012 as a new local group to oversee biosecurity issues across Riverina horticulture industries. Its current charter is to educate the local community and growers about QFly management. The ultimate aim is a grower self-funded bait spray programme across all Riverina horticulture at an estimated cost of AUS\$3.75 million per year (Davidson & Davidson 2012).

The Riverina Biosecurity Executive Committee comprises of representatives from Citrus Australia,



Horticulture Australia Limited, Local Land Services, NSW DPI and three local grower association bodies. Citrus Australia provides assistance with interpreting market access protocol requirements and by lobbying government about QFly-related issues. Other horticulture industries show little interest in participating while QFly is of little economic significance.

A new part-time local QFly coordinator started engagement with key local stakeholders. A fruit fly expert was contracted to lead workshops for growers and town residents about QFly management. Some respondents felt that local knowledge is being overlooked, including the input from credible, local growers who are informally experimenting with QFly management.

### 3.3. Young–Harden, New South Wales

Cherry growers are the main group pushing for FF AWM as despite negligible QFly damage the pest hampers market access, including the need for cold treatment to several markets.

Between 2003 and 2006, the NSW DPI carried out QFly-related research in Young–Harden and identified potential for AWM. Progress in strengthening market access is hampered by a lack of a current QFly CoP to provide guidance about trapping methods acceptable to markets (Marte 2007). Several respondents were frustrated with the lack of information about what would satisfy prospective markets.

In October 2012, the Young and Harden shire councils and local growers formed the Fruit Fly Action Group to address QFly in response to restricted market access concerns. Most group members were chosen for their expertise, knowledge and involvement in other related networks. Local governments, in particular the Young Shire Council, play a key role in driving the group's activities. Some group members have a good relationship with a NSW DPI QFly researcher, including formal and informal trials happening on growers' land. On-ground progress is challenged by people with little incentive to address QFly, including various town residents, lifestyle and absentee landholders.

## 4. Discussion

This section is structured around the five key components of adaptive co-management (Plummer & Armitage 2007).

### 4.1. Social learning

AWM requires an in-depth understanding of the local QFly situation, including QFly biology within the crops involved, how and when the pest moves and what non-commercial plant hosts support it (Clarke et al. 2011). With limited state government assistance,

greater onus rests on local stakeholders to carry out and fund activities that will deliver such knowledge.

The Central Burnett programme is underpinned by a thorough understanding of local QFly behaviour. Social learning occurred between crop consultants, QDPI researchers and some growers through collaborative sense-making drawing on different knowledge systems, including lessons learned elsewhere. The broader grower community shaped the local QFly-related research plans and learned by implementing some new technologies, i.e. male annihilation technique. This kind of participatory research is likely to spark discussion and learning, and often strengthens social capital (Pretty 1995). In the Riverina and Young–Harden, there are growers experimenting with QFly control measures suggesting that there is local interest in participating in learning activities. This could be drawn into more formal social learning processes, such as growers collaborating with a researcher.

In the successful Hawaii FF AWM programme, growers are seen as adult learners, that is, "autonomous, self-directed, relevance-oriented individuals who took responsibility for their learning and enjoyed cooperative learning environments" (Mau et al. 2007, p. 673). At the start, growers were required to sign agreements delineating their personal responsibilities to secure support. They were obliged to undertake hands-on learning by implementing prescribed on-farm fruit fly control techniques following an agreed schedule (Mau et al. 2007). Participatory implementation changes land managers from passive recipients of pest management advice to self-reliant, active practitioners of pest management (Pretty 1995).

Knowledge content is not the only motivator for adoption (Pretty 1995). How people perceive that knowledge has been generated and under which conditions also determine their willingness to adopt practices (Pretty 1995; Cote & Nightingale 2012). Local evidence of towns being hotspots for QFly and the success of interventions during the AWM trial convinced many Central Burnett growers to contribute financially to town treatments after the trial ceased (Lloyd 2007). A Riverina respondent said:

Whatever campaign or strategy they come up with... it has to be based on evidence from around here. [External expert] can come all he likes and say it works in [location elsewhere] and everyone goes 'who cares?!'. It's got to be a strategy developed here for here given the crops the growers grow here and everything else that goes on here. It will need a totally different strategy than anywhere else.

Social learning also requires attentiveness to process knowledge, such as how organisations, groups and individuals best interact and how learning processes can be optimised (Olsson et al. 2004). In the Hawaii FF AWM "word of mouth" between growers was an important pathway for adoption, and personal



communication was more effective than print materials (Vargas et al. 2008). Some Young–Harden growers pointed to the importance of encouraging local constructive conversations about QFly control and the value of learning from each other.

All three cases show the need for local stakeholders to have the opportunity to learn about the complexities and requirements around achieving market access to QFly-sensitive markets to shape their expectations.

However, social learning is not without challenges. Whilst it provides a key means for building local capacity, it offers little in addressing the motivations, such as self-interest, underlying people's behaviour (Leeuwis 2000), when considerable proportions of the regional community have little incentive to control QFly. Individuals' interest in social learning about a resource is strongly related to the personal risk posed and their dependence on the resource (Ruitenbeek & Cartier 2001). The reluctance of other industries to be represented on Riverina Biosecurity is a prime example. Hence, heterogeneity amongst potential participants might complicate social learning (Muro & Jeffrey 2008).

#### 4.2. Communication

Central Burnett demonstrates that trust between different stakeholders to sustain effective communication is fundamental. Repeated meaningful interactions involving open communications foster trust relationships and facilitate a shared understanding (Lebel et al. 2006; Armitage, Plummer, et al. 2008). Both the quantity and quality of interactions are important (Measham et al. 2012). In particular, face-to-face interactions are known to foster a group identity, trust and a sense of shared purpose (Marshall 2004).

Central Burnett exhibits trust-based communication between crop consultants and their grower clients. During the trial, these trust relationships also extended to the state government researchers. In Hawaii, a shared vision and objective for fruit fly control was achieved through several "candid" discussions with key stakeholders (Mau et al. 2007). Young–Harden respondents consider the existing trust between Fruit Fly Action Group members as an asset that stems from previous non-QFly-related collaborations. In the Riverina, lack of trust developed for a range of reasons, including past tensions that led to the demise of Riverina Citrus, different on-farm objectives and various identities based on location or cultural background.

Effective communication requires both "within group" bonds and bridging "between groups" bonds (Coleman 1988; Bodin et al. 2006). Information needs to circulate within groups, e.g. horizontally within certain local commodity groups, local town communities and local government staff, as well as between vertically aligned groups, such as between government

departments and industry bodies. Locally effective communication facilitates shared understanding and collective action to address the issue. Vertically, it relates to information flow with different groups providing support, e.g. for market access and for locals to stay abreast of QFly control developments.

Information brokers are required to link and facilitate effective information flow between groups. These individuals typically understand the "inner life" of different groups and the continual change that happens in them (Bodin et al. 2006). The data suggest that brokers are more prevalent towards the local level, such as Central Burnett crop consultants or Young–Harden Fruit Fly Action Group members who are involved in other industry-related groups. Information brokers between local industries and the market access negotiation arena, especially for international export, are lacking. In the Riverina, Citrus Australia plays this role to some extent. All three case studies had limited access to individuals with in-depth insight into international market access processes and many were frustrated with a lack of downward information flow from Australian Government officials who have insight into how to maximise trade opportunities.

We should be getting a lot more information from DAFF [the then Australian Department of Agriculture, Fisheries and Forestry] saying this is the sort of problems we encounter when we do negotiations... DAFF should be more proactive and coming to us and saying here are the issues we had with [certain country], here are some of the gaps we need industry to work on...such information will give us more clout when they go back and start talking trade. (Young–Harden Focus Group participant)

Likewise, feedback loops to decision-makers are often lacking about the inefficiencies caused by their decisions and lessons learned on the ground (Allan & Curtis 2005; Berkes 2007b; Folke 2007). For the case studies, this includes the impacts and costs associated with government staff turnover and the associated social memory loss; a lack of guidance about acceptable QFly control procedures for market access and complying with impractical on-farm market access requirements that are the outcome of government-to-government market access negotiations. Young–Harden respondents pointed out that meeting with government staff increases mutual understanding of the barriers and opportunities that each party faces.

#### 4.3. Adaptive capacity

Adaptive capacity is a corollary of sustained social learning and effective communication between stakeholder groups horizontally and vertically (Armitage 2007). The Hawaii programme demonstrates that monitoring and evaluation activities throughout the programme's lifetime, starting from programme



planning, support social learning and are crucial to ensuring that the programme remains on track. This relates to both the pest control and social components of the programme (Mau et al. 2007). Central Burnett shows that the involvement of locals, who have a long-term commitment to the industry and having readily, continued access to QFly control expertise, supports adaptive capacity. Local social learning processes together with minimal change to the management group membership result in a high level of social memory about what works and does not work in the local context (Olsson et al. 2004; Folke et al. 2005; Bodin et al. 2006). The management group meeting minutes reveal that when change is introduced to adapt, such as altering town treatments to adjust to lower grower contributions, results are closely monitored to ensure that the system does not lose functionality. It emphasises the importance of context-specific, local knowledge about QFly behaviour and control to be able to adjust to perturbations. Effective leadership is required to drive such adaptation processes (Folke et al. 2005), as is exemplified by the Central Burnett management group.

#### 4.4. Shared decision-making

The planning of the Central Burnett AWM programme and the research leading up to it were done collaboratively between the state government researchers, crop consultants and local growers involving meetings and other forms of personal contact.

Effective social learning and negotiation are unlikely to happen if it is not embedded in well-managed processes (Leeuwis 2000). Process knowledge and skill are required for shared decision-making, as power relations can skew decisions and ultimately outcomes (Muro & Jeffrey 2008; Leys & Vanclay 2011). Deliberative processes can fail if not well facilitated (Garmendia & Stagl 2010).

This implies that members of local management groups need to be selected not only based on which organisation they represent, but also on skills, influence and personality traits. In Hawaii, management group members were selected based on whether they can commit to a shared vision, had good two-way communication skills, were flexible, had an aptitude for consensus-building and would sustain mutual trust between members (Mau et al. 2007).

Deciding on priorities in the management process invariably requires making trade-offs (Anderies et al. 2004). In Young–Harden, the involvement of others who have been involved in QFly management and AWM elsewhere, as well as in market access processes, is valuable in providing guidance in prioritising activities. However, when decisions involve trade-offs between local social and pest management objectives, such as the level of QFly control and how to deal with

risk contributors with little incentive to control QFly, decisions need to be negotiated locally to be rooted in the local socio-economic, cultural and political context. External “experts” should not determine these decisions (Lebel et al. 2006).

Shared decision-making also implies that growers need to feel represented on the management group to garner their support for decisions. This is more challenging in areas with fragmented grower communities, such as the Riverina, and will require additional investment in engagement and relationship-building.

#### 4.5. Shared authority

In the biosecurity and trade context, a large power differential exists between horticulture industries and government agencies, which stems from the roles and responsibilities governments have under international and national biosecurity and market access institutions.

Adaptive co-management theory emphasises the importance of power-sharing and identifies policy and regulatory frameworks as key barriers (Plummer & Armitage 2007). In the complex market access context, there is tension between “bottom-up” and “top-down” approaches. “Top-down” or “command-and-control” dimensions are known to undermine both social learning (Gunderson & Holling 2002) and locally tailored management approaches (Prager & Vanclay 2010).

In the domestic context, there is evidence of “top-down” and “bottom-up” approaches. Examples of ICAs representing “top-down” approaches include ICA-56 Emergency Pre-harvest Baiting and Inspection Protocol for Pest Free Areas as well as others dealing with post-harvest treatments. More “bottom-up” approaches are reflected in those ICAs that have been developed involving growers, researchers (often from state governments) and funded by the national research and development body with levy funds co-matched by the Australian Government. Examples include Central Burnett’s ICA-28 and ICA-34 Pre-harvest Field Control and Inspection of Strawberries (South East Queensland produce only). Challenges include difficulty in getting all states to accept all ICAs (NFPS Implementation Committee 2009), the use of levy funds is controversial (ACIL Allen Consulting 2014) and these protocols are costly and time-consuming to develop (Clarke et al. 2011). These are some of the reasons driving harmonised protocols that can be widely applied.

Moreover, grower respondents emphasised that market access negotiation is an area where they have limited control. Sometimes, markets are lost due to changing rules in importing countries. For example, Young–Harden lost the Taiwan market at the end of 2005 after this country upgraded its quarantine requirements, despite no QFly ever detected in traded produce for over 20 years (Marte 2007). Several



respondents mentioned that some market requirements are illogical, costly and impractical. Gaining market access is also tied-up in political processes, despite the WTO's intention to have it purely science-based (Maye et al. 2012). Changing market access rules can be lengthy, expensive processes. For example, making protocols more workable on-farm could take many years when generating data are required to prove that alternative methods can sufficiently manage QFly risk.

Hence, if achieving access to particular markets is the sole objective of an AWM programme, the market access process can frustrate sustained support for all programme components. This suggests that the main focus of AWM programmes ought from the outset be to protect the local industry from current and potential increases in QFly pressure, regardless of what markets require. Market access requirements need to be seen as added components to these programmes.

Moreover, FF AWM programmes need some centralism mostly contained in the management groups for coordination and to support adaptive capacity (Bodin et al. 2006). Hendrichs et al. (2007) point out that AWM programmes often cannot function without "top-down" elements, such as regulation to secure support from risk contributors. However, these programmes can also not function without the positive support from growers and town communities and effective engagement is fundamental to complement and shape "top-down" approaches (Hendrichs et al. 2007; Vreysen et al. 2007).

Strong representation of different local groups, shared decision-making – including quality negotiation and facilitation processes – and a clear understanding of what is negotiable and what is not, are cardinal in developing well-supported AWM programmes. Representation on AWM management groups needs to allow for the views of different groups affected by the AWM programme to be considered during decision-making (Jennings & Moore 2000).

## 5. Conclusion

Fundamentally, adaptive co-management calls for a shift in focus from implementation only to implementation based on continual learning involving various knowledge systems (Allan & Curtis 2003; Janssen & Anderies 2007). Important here is that these activities not only increase participants' knowledge but also build local momentum and ownership of QFly issues and, thus, create the much needed shared vision and collective knowledge base about local QFly issues. This is likely to contribute to support for such programmes, but will not guarantee support from all risk contributors.

Social learning can start with a small group of interested growers and other local stakeholders, such as crop consultants or local government staff, in

conjunction with external QFly experts. The group sets learning priorities and decides how the group will function.

Adaptive co-management is only workable if it is nested in an enabling environment (Ostrom 2005). This on-ground perspective presented here suggests a number of ways in which government and industry bodies can encourage local industries to engage in such processes:

- Encourage social memory and sustained situational thinking (Plummer & Hashimoto 2011) by minimising staff turnover of officers interacting with growers.
- Give preference for research projects involving participatory approaches with growers.
- Insist on best practice engagement components in on-ground programmes, including prioritising funding for these components. In particular, make monitoring and evaluation of stakeholder engagement a requirement, such as the programme logic approach (Mau et al. 2007; Kruger 2012).
- Invest in making experts available to guide grower groups in learning processes, including continual sense-making for the local context.
- Develop and offer training packages to growers and other local stakeholders for capacity building, including basic skills in research, monitoring and evaluation and group facilitation.
- Prioritise two-way information flow between growers and government decision-makers. In particular, invest in information brokers across on-ground, state and national levels.
- Invest in people that can guide local industries through the market access process.
- Nurture a workplace culture where maintaining trust and strong relationships with grower groups is prioritised.
- Revising and releasing an updated QFly CoP and other forms of guidance is a matter of priority.

Ways forward for growers and growers groups:

- Create forums for interested growers to meet regularly, interact, learn collaboratively and take collective decisions (Muro & Jeffrey 2008). Encourage representation across groups.
- Engage others in the region that could make a contribution, e.g. packhouses, local government, chemical suppliers and gardening groups.
- Engage with experts in on-ground fruit fly management and market access.
- Find existing information, including engaging those with knowledge of the region's QFly history and retrieving past trapping data from state government where available. Learn from other regions.



- Ensure that local management group members represent all local groups where possible.
- Consider personality traits when inviting people to join the management and/or learning group, including influence with other growers, aptitude for consensus-building and good two-way communication skills.
- Prioritise building and maintaining trust with all QFly host owners in the region as well as other stakeholder groups, such as government and industry bodies.
- Invest in leaders and champions, including capacity building where needed, as they are crucial in attitudinal and behaviour change (Pahl-Wostl 2006; Mau et al. 2007).

Adaptive co-management offers neither "quick fixes" nor cheap solutions to local QFly issues. Significant transaction costs can be expected at the start for capacity-building, but over the long run, this approach leads to more sustainable, locally owned systems (Pretty 1995) that stand the best chance to continually adapt to QFly-related challenges. It offers a solid foundation for additional market access requirements.

For adaptive co-management theory, this work illustrates that the influence of the market and the biosecurity institutional context presents top-down elements. Different markets lead to different on-farm objectives for QFly control, which can complicate finding a shared vision for regional QFly control. However, this is best dealt with by locals remaining focused on minimising local QFly pressure, despite market objectives and demands.

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### **4.3 Article 3. ‘Smart regulation’ and community collaboration in Australia’s modern biosecurity context**

A key challenge to industry-driven AWM is achieving wide-spread voluntary cooperation amongst fruit fly risk contributors, including growers, town residents and other landholders. Case study findings; theoretical considerations about the role of the community in biosecurity; and experiences elsewhere contributed to identifying four options for dealing with this challenge. This manuscript is under review with the journal *Rural Society* – the first round of reviewers’ feedback has been incorporated.

## **“SMART REGULATION” AND COMMUNITY COLLABORATION IN AUSTRALIA’S MODERN BIOSECURITY CONTEXT**

Increasingly resource-constrained governments encourage greater industry and community self-reliance. This research investigates the potential use of “smart regulation”, that is, complementary policy instruments in a context where reliance on voluntary approaches to achieve local cooperation is problematic. It explores the case of industry-driven area-wide management (AWM) of fruit fly, a potentially devastating mobile pest. AWM involves synchronized pest management across a geographical area. As host plants beyond commercial farms, e.g. in nearby town backyards and peri-urban areas, create fruit fly breeding places, pest management activities are also needed here. In Australia, most local horticulture industries are expected to drive these initiatives to minimise damage to their crops and market opportunities. AWM offers an example of where the beneficiaries are concentrated, but the risk contributors are diffused. Mixed-methods research was applied involving three Australian case studies. Considerations for four policy instruments that could be included in a “smart regulation” approach are explored. The research shows that applying “smart regulation” promises a prudent way forward when governments expect industry self-reliance, but where industry has limited influence over diffused risk contributors.

**Keywords:** area-wide management; biosecurity; community engagement; fruit fly; partnerships; shared responsibility

### **Introduction**

In many countries “top-down” government approaches have made way for alternative policies often featuring partnerships and shared or devolved responsibilities with industry and the community (Morrison and Lane, 2006; Lockie and Higgins, 2007; Berkes, 2010). In rural Australia, this often leads to reliance on voluntary approaches to encourage farming and town communities to contribute to accomplishing certain outcomes (Gunningham, 2009; Curtis, 2000; Curtis et al., 2014). However, these approaches are challenged when the main beneficiaries are concentrated, yet the costs are diffused across many risk contributors. Here such an example is explored from the

plant biosecurity world. Australian biosecurity is a prime example of where the state increasingly devolves responsibility to other societal sectors (Higgins et al., 2016).

Queensland fruit fly is a mobile pest that can devastate horticulture crops and it can hinder market access even without production impacts (PHA, 2008). It poses a serious threat to Australia's fruit and vegetable industry worth almost AUS\$8 billion in 2014-2015 (ABS, 2016b). QFly management has recently become more challenging in Australia with the restriction of key pesticides, fenthion and dimethoate, traditionally used to control the pest (APVMA, 2012). Area-wide management (AWM) is promoted as a key control strategy (NFFC, 2016) as, if successfully implemented, it lessens dependence on pesticides (PHA, 2008). It refers to coordinated pest management activities implemented over an extended area. As host plants in town backyards, peri-urban and public land present pest breeding places, pest management activities are also required here (Hendrichs et al., 2007). Hence, the AWM success depends *inter alia* on community collaboration.

A lack of public support is a greater contributor to AWM program failure than poor technology (Dyck et al., 2005). Community engagement is needed to both encourage support and address community concerns (Hendrichs et al., 2007). This work focuses on gaining community support to prevent QFly infestation from their land.

This article explores how suitable is “smart regulation” as an option for managing pest pressure from land beyond affected commercial orchards. “Smart regulation” involves complementary policy instruments in a context where reliance on voluntary approaches to achieve local cooperation is problematic (Martin and Gunningham, 2014; Australian Public Service Commission, 2009; Kennedy, 2010). It starts by canvassing the changing roles of the state, industry and the community, including in the Australian biosecurity context; and how regional pest issues are addressed elsewhere. Data is

derived from mixed methods including three case studies. Four policy instruments that could potential be included in “smart regulation” are explored. This article contributes to the broader discussion about making the modern biosecurity project workable, including gaining community support.

## **Literature review**

### ***The changing roles of the state, industry and community in NRM***

Recent decades have witnessed an increase in approaches that emphasise community involvement in natural resource management (NRM) (Curtis et al., 2014). Broadly speaking, by the 1980s traditional “top-down” government approaches were criticised for being inefficient and inflexible (Berkes, 2010; Morrison and Lane, 2006). These critiques coincided with increasing neoliberal rationales favouring market-driven approaches, deregulation (Maye et al., 2012) and greater industry and community self-reliance (Lockie and Higgins, 2007). This included an increased reliance on voluntary approaches to address NRM issues (Gunningham, 2009; Curtis, 2000). The emphasis on key neoliberal themes such as deregulation and a smaller state contributed to the term “roll-back” neoliberalism (Lockie and Higgins, 2007; Peck, 2010; Maye et al., 2012).

However, from around the mid-1990s, the limitations of simplistic deregulation became clear, including with voluntary schemes (Gunningham, 2009), contributing to “roll-out” neoliberalism (Maye et al., 2012; Peck, 2010). That is, the introduction of various innovative regulations and policy adjustments that reinforce “market rule” to address challenges associated with neoliberal governing (Maye et al., 2012; Peck, 2010), while ensuring programs are workable and legitimate (Lockie and Higgins, 2007).

“Smart regulation” forms part of such innovative approaches. It is defined as “a form of regulatory pluralism that embraces flexible, imaginative and innovative forms of



social control” (Gunningham and Sinclair, 2017: p133) Using a combination of instruments assists in overcoming the weaknesses of individual instruments, while capitalising on their strengths (Australian Public Service Commission, 2009). For example, by combining approaches that draw on people’s intrinsic motivation to “do the right thing” with enforceable, legal instruments (Kennedy, 2010). It often involves a combination of either regulation with self-motivation and/or local empowerment, including forms of self-regulation or co-regulation (Gunningham and Sinclair, 2017).

### ***Community engagement***

The shifting roles of society’s three main sectors have triggered a proliferation of community engagement literature. Much are based on the public participation rationale, which broadly involves giving communities greater self-determining powers by engaging community members in setting agendas, making decisions and other forms of policy-making (Rowe and Frewer, 2005). Proclaimed benefits include better understanding of issues, strengthened trust, communication and learning between citizens and government; and hence improved decision-making that enjoys higher legitimacy amongst participants (Creighton, 2005).

Several authors are concerned that in the context of neoliberal thinking citizens can be seen as mere “implementation agents” with a shared responsibility that need to be mobilised to contribute to achieving certain outcomes (Curtis et al., 2014; Gill, 2011). Hence, this easily leads to a way of thinking that focuses on what the community needs to do to achieve predetermined outcomes. The danger here is that such thinking could result in over-optimism about what could be achieved through voluntary community contributions (Curtis et al., 2014). People in rural areas may hold a different interpretation than the state of what their responsibilities are (Higgins et al., 2016). Some point out that responsibility endowed does not necessarily mean responsibility accepted (Gill, 2011).

Curtis et al. (2014), a group of social scientists with extensive experience in NRM, have identified key lessons about best-practice engagement based on voluntary community-based NRM in Australia and New Zealand over the last 25 years. It is a response to their concern that communities are increasingly seen as “implementation agents” rather than being truly enabled to address NRM issues. Lessons include the need for voluntary collaboration to tap into the community’s intrinsic motivations. Governance responsibilities and rights are best devolved to the “lowest” level possible where they can be implemented effectively. Adoption requires a multi-pronged approach addressing all key barriers to behavioural change, but education has become the main focus as it is seen as a low-cost solution. Voluntary cooperation requires investment in strengthening local self-help, including capacity building. They point out that voluntary cooperation is not appropriate in all contexts.

### ***The role of the community in the Australian biosecurity context***

The modern biosecurity paradigm in Australia emphasises partnerships and shared responsibility, including a greater role for the community (Nairn et al., 1996; Beale et al., 2008). It has brought with it reduced public investment for domestic biosecurity and the devolution of responsibility (Higgins et al., 2016). However, tension exists around the community’s role. On the one hand it seems fair that all Australians have responsibility to preserve biosecurity as they benefit from better food security and quality, stronger trade and greater environmental preservation (Fraser, 2016). On the other hand, some question whether the community is a true biosecurity partner, as it has limited opportunity to shape the agenda (Barker, 2010). Plant biosecurity challenges seldom become key election issues and society at large is generally ignorant about plant pests (Brasier, 2008). Donaldson (2013) posits that in these contexts the community’s biosecurity responsibilities may become an extension of government and agriculture industries’ biosecurity apparatus, often for trade-related aims. Higgins et al. (2016)

found that while governments might be driven by a logic of biosecurity partnerships and shared responsibility, this is likely to be challenged by alternative institutional logics at the local level.

### ***The community and area-wide management***

Currently, in most Australian horticultural regions state governments require local industries to take the lead in securing the voluntary support from local landholders with QFly host plants on their properties. Australia's National Fruit Fly Council (NFFC) states that, "local grower groups are encouraged to work with their local councils to help educate residential communities about how to manage their gardens against fruit fly" (NFFC, 2016). There are some instances of innovative policy mechanisms to deal with QFly. For example, in the Great Sunraysia region in Victoria, a grower levy has been legislated (Agriculture Victoria, 2015) to enable a funding stream for industry to deal with, amongst other, pest pressure from towns.

Australian noxious weed management traditionally rest on legislation enforcing landholders to manage key weeds on their land. However, there are increasingly calls for more innovative approaches involving collective action between landholders across an area (Marshall et al., 2016). Sindel et al. (2013) investigated how to improve regional weed management adoption by exploring serrated tussock (*Nassella trichotoma*) control. They favour a community-based approach based on cooperation and trust, but concluded, "A community-based program to engage the community in weed control (a "carrot") must ... be accompanied by sufficiently strong legislative requirements to control weeds, both on private and public land (a "stick")" (Sindel et al., 2013: xviii).

"Smart regulation" is also evident in some overseas examples of achieving community collaboration for horticulture-related pest management. For example, in the US states of Washington and Oregon the state provides certain powers to local groups called horticulture pest and disease boards. These grower-run groups are formed once

25 growers within a region file a petition to their local government to express their concern about pest pressure from other landholders' land (including towns). Local government has the power to approve such boards under the 2011 Washington Code (Title 15 Agriculture and Marketing, 15.09 Horticultural Pest and Disease Board). The boards, which typically also run community education campaigns, have powers such as the ability to enter private property, inspect land and order landholders to control pests.

In Canada's British Columbia province, The Sterile Insect Release (SIR) program for Codling Moth control, is underpinned by provincial legislation. Programs involving sterile insect technique are typically based on AWM. The Municipal and Validating Act (1989) makes provisions for bylaws that allow for the establishment of Codling Moth SIR programs overseen by autonomous boards in five districts. Three out of the eight board members are local growers. Program staff have powers to enter private property, inspect land and order landholders to control pests. These activities are complementary to community education efforts (Anon., 2011).

Like Greater Sunraysia, some overseas programs have legislated funding mechanisms. In parts of South Africa, if the owners of 70 per cent of the area under production within a region are supportive of fruit fly sterile insect technique (SIT), the government launches an economic study to investigate if all growers are able to contribute to it. If so, contributing to and participating in the SIT program becomes compulsory. Part of this funding, which is matched by government funding, is used to resource regional coordinators as well as fruit fly control and community education activities in towns (personal communication, Nando Baard, FruitFly Africa, December 2014). The Canadian SIR Program for Codling Moth is primarily funded by a parcel tax for horticulture growers (charged per acre under horticultural production) plus a property tax on rural and urban properties in the region. This funding enables, *inter alia*, pest management activities in towns (Anon., 2011).

## **Research methods**

The mixed-method research presented here explores how suitable a “smart regulation” approach is for managing pest pressure from land beyond affected commercial orchards. It does this by exploring four prominent policy instruments that are typically used in similar contexts. Understanding the strengths and weaknesses of different instruments assists in understanding if there is a need for using complementary instruments.

### ***Empirical research***

The qualitative research involved fieldwork conducted in three case study regions that each involve attempts to stem QFly pressure from local towns. An interpretivist approach (Denzin and Lincoln, 2000) based on case studies were chosen to tease apart the interwoven variables and complex relations involved (Punch, 2005). In particular, this research explored the challenges and opportunities that local grower groups face in pursuing AWM, including engaging their local communities to manage QFly. These cases (see Table 1) were selected using theoretical sampling (Eisenhardt and Graebner, 2007) to achieve maximum social and institutional variation. None of them envisage QFly eradication; rather the medium-term focus is achieving/maintaining an on-going collective approach to QFly management. Community refers to all residents who are not part of the main local industry group driving the AWM initiative.

Primary data were obtained from face-to-face, in-depth, semi-structured interviews with key informants. They were selected using purposive sampling, i.e. people were chosen based on their knowledge, position or characteristics (Punch, 2005) and to ensure variety of perspectives (Eisenhardt and Graebner, 2007). Interviewees were chosen based on occupying key roles in the AWM attempt and on their understanding of how key stakeholders, such as growers and/or the local community, respond to the QFly challenge. They included program coordinators, growers, crop consultants, and representatives from local and state governments and packhouses. Focus groups with

the local management group members overseeing the AWM initiative were also carried out. All participants provided written informed consent to participate. The questions asked were broad and open-ended to obtain honest views (Punch, 2005) about the *status quo* of the AWM program. For example, respondents were asked what they thought of the support they received from town residents, other landholders and government bodies. Other data sources included observing management group meetings, and drawing on existing reports, previous management group meeting minutes and media releases, where available.

**Table 1. Overview of the case studies and data collection**

<b>Case study</b>	<b>Central Burnett, Queensland</b>	<b>Riverina, NSW</b>	<b>Young-Harden, NSW</b>
<b>Industry driving AWM</b>	Citrus (mainly mandarins)	Citrus (mainly oranges)	Cherries
<b>Why chosen</b>	Success story of industry-driven AWM. The town community is regarded as supportive (Lloyd et al., 2010).	Large, diversified region which had much past government support. Since July 2013 coordinated QFly management attempts are industry-driven (Davidson and Davidson, 2012).	Since 2012, growers initiated a group to coordinate regional QFly management. Local government plays a key role.
<b>Qualitative data</b>	Thirteen interviews One focus group October 2013	Twenty interviews One focus group March 2014	Nine interviews One focus group September 2013

<b>Case study</b>	<b>Central Burnett, Queensland</b>	<b>Riverina, NSW</b>	<b>Young-Harden, NSW</b>
<b>Survey response rate (No. of respondents / Total grower population)</b>	70% (28/40)	51% (50/98)	63% (20/28)

Interviews proceeded on average for an hour, were audio-recorded and transcribed verbatim. Data was coded by one researcher using NVivo 10. Coding involved an iterative process of continuing checking and refining codes and emerging themes as data came in. Initially coding was based around stakeholder groups, such as local government, state government, growers, other landholders, town community; as well as program background, institutions and other. As key themes became apparent sub-nodes were added (Denscombe, 2014). For example, “communication” was a common sub-theme under each group. “Supportive” and “non-supportive” became sub-themes under growers, other landholders, town community, which were later considered together to understand enablers and hindrances for AWM support. Member checking was used to verify findings (Punch, 2005) by sending a summary of each case study’s findings to the related interviewees for comment.

The quantitative research involved a grower survey conducted in the same regions between September and November 2015. As local grower groups are responsible for driving community engagement initiatives, the survey explored how growers perceive QFly risk from towns and how it is dealt with. The survey implementation process was based on the guidance provided by Dillman et al. (2014). Contact details were obtained from either the local management group or industry associations. Most responses were

received electronically through SurveyGizmo, while some growers submitted hardcopies or completed it over the phone with a researcher. The response rates are contained in Table 1. Due to limited fieldwork resources only two out of the five local government areas in the Riverina were surveyed, that is, Leeton and Carrathool. This was based on the preference of the local management group, Riverina Biosecurity Incorporated. Small grower population sizes meant that analysis of responses was limited to calculating percentages per respondent population for each case study.

The development of the questions was informed by the preceding qualitative research findings. Central Burnett growers were asked different questions than the growers in Riverina and Young-Harden, as Central Burnett relies on voluntary grower contributions to fund town treatments, whereas the other two case studies rely on awareness-raising and education. All growers were requested to indicate to what extent they agree or disagree with a statement. For Central Burnett the statements were:

- Towns can be a serious risk to QFly pressure in our region if left unmanaged
- All horticulture growers contribute the recommended amount for their property to manage QFly in towns
- I will only contribute to town treatments if all other growers contribute too
- I contribute the full recommended amount to the town treatments

In the Riverina and Young-Harden the statements were:

- QFly breeding in towns increases QFly pressure for horticulture farms in our region
- All town residents understand the QFly issues faced in our region



- Town residents will sufficiently manage QFly in their yards when there are regular education and awareness-raising activities
- QFly treatments on public land are an effective way of reducing QFly pressure in our region (such as baiting, trap monitoring and MAT blocks along town streets)

The survey findings were considered together with the qualitative data that dealt with community support and the role and support of different stakeholder groups. This was compared with a literature review about NRM community engagement as well as how overseas AWM case studies deal with the issue of pest pressure coming from land beyond commercial farms. The Australian National University Human Research Ethics Committee approved the research proposals for the qualitative and quantitative research.

### ***Identification of the policy instruments***

The policy instruments that are explored in the Discussion section were identified from the case studies, literature review and overseas cases (Table 2).

**Table 2. Reasons for the choice of policy instruments to be explored**

<b>Policy instrument</b>	<b>Reason why chosen</b>
Voluntary approaches	Commonly promoted in Australia
Broad-based state regulation	Can easily be seen as “quick fix”
Devolved power	Some forms used in overseas cases and other “public participation” forms are promoted in community engagement literature
Legislated cost recovery-structures	Present in overseas AWM programs and since recently in Greater Sunraysia, Victoria

## **Findings**

This section gives an overview of each case study's narrative as identified through the semi-structured interviews, focus groups and related documentation. It is followed by a summary of the survey findings.

### ***Central Burnett, Queensland***

Once a significant endemic pest that sometimes devastated crops, QFly is now a minor pest. AWM started in 2003 as a trial led by state government and local private crop consultants, and included the appointment of the Central Burnett Fruit Fly AWM Management Group. Local government was instrumental in community engagement activities early on and continues to provide some support.

The towns of Gayndah and Mundubbera are relatively small (1,789 and 1,042 residents, respectively in 2011 (ABS, 2013)), making it feasible for growers to fund backyard QFly treatments with voluntary contributions. Since AWM started, town residents were asked to permit a contractor to enter their backyards to perform regular QFly management activities. Several respondents spoke about positive feedback from the community as they can now enjoy maggot-free backyard produce. Engagement with town residents commenced before the program started, including public meetings, advertising, and media releases.

However, grower contributions for town treatments are dwindling, due to both witnessing others not contributing while enjoying the same benefit and not achieving the anticipated strengthened market access directly attributable to AWM. After years of good outcomes, many growers are uncertain whether town treatments still lessens on-farm QFly pressure. Town treatments have recently been changed to save cost. Results are closely monitored.

### ***Riverina, New South Wales***

The Riverina faces the most challenges of the case studies. This extensive area includes five local government areas, i.e. Carrathool, Griffith, Leeton, Murrumbidgee and Narrandera. Since July 2013, the citrus industry has driven an attempt for coordinated QFly control, as the pest hampers market access, especially for export navel oranges. Grower uptake is challenged by heterogeneous on-farm objectives. For example, several respondents referred to numerous Riverina landholders living on 30 acre blocks with old citrus orchards that are not their main livelihood. Removing orchards is expensive and work commitments elsewhere prevent rigorous QFly management. In years of good citrus prices, these orchards can still provide income by selling fruit for juice. Moreover, many of the region's other horticulture producers experience little economic impact from QFly, despite these commodities being declared hosts. Frustration with those failing to control QFly and their ignorance of its impact was common.

The area includes Griffith, a large rural centre, and the towns of Leeton and Hillston (17,616; 8,414 and 1,430 residents respectively (ABS, 2013)). Town suburbs are adjacent to some commercial orchards. There is a long history of strong state government-supported QFly control. The New South Wales Department of Primary Industries (NSW DPI) used to work with the then Riverina Citrus, a local industry association, and local shire councils to manage QFly populations in towns. In July 2013, the NSW DPI handed QFly control over to industry after unprecedented QFly detections left the prevailing management approach economically unsustainable (NSW DPI, 2012). NSW DPI sees its current roles relating to the broader community as providing technical information and producing information hand-outs and websites. Local government's involvement ceased when NSW DPI reduced their on-ground activities.

Riverina Biosecurity Incorporated started in September 2012 as a management group to oversee horticultural biosecurity issues, starting with QFly. It organises QFly control workshops for growers and town residents to encourage application of baiting, trapping, crop sanitation and netting, although attendance can be challenging. RBI appointed a Riverina Fruit Fly Campaign Coordinator in December 2013, funded by the then Horticulture Australia Limited, to strengthen community and grower support for QFly management.

At the time of the fieldwork, The Plant Diseases (Treatment and Eradication of Queensland Fruit Fly, Riverina) Order No. 45, 2011 under the Plant Diseases Act 1924, required Riverina landholders and residents to treat citrus and prune plants for QFly. However, this regulation was not strongly enforced, which frustrated many respondents. Apart from the state government lacking enforcement resources there was a moral dilemma, as the quote below illustrates:

*If you have a man of 75, living on his five acre block, he is retired or semi-retired, he has contributed to society ...should we legislate him out of what he has chosen to do for his retirement when he is a self-funded retiree? ... And should we then say we demand you do something and he is broke? ... There is no easy way out of this. And we get into the very sticky area of where the industry believes something should happen ...and are they going to ask government to force an industry view onto another sector of society?*

(NSW DPI representative)

At the time of writing this legislation was no longer in place. Respondents lamented the lack of local power to deal with landholders (both urban and orchardists) not controlling QFly.

### ***Young-Harden, New South Wales***

Between 2003 and 2006, the NSW DPI carried out QFly-related research in Young-Harden and identified the potential for AWM. QFly trap counts were far greater in

towns than in commercial orchards (Marte, 2007). Some commercial orchards are adjacent to Young suburbs, whereas Harden is removed from orchards. They have 10,039 and 1,877 residents, respectively (ABS, 2013).

In October 2012, the Young and Harden shire councils and local growers instigated the Fruit Fly Action Group to coordinate QFly management in the region. The cherry industry drives QFly control, as the pest hampers markets access opportunities. Local governments play a key role in the Fruit Fly Action Group's activities, including external networking and applying limited QFly control on public land in towns during peak QFly periods.

A strong theme was the lack of local power to compel those with little incentive to control QFly. The group recently started engaging the community including through media releases, radio talks, letterbox drops and community meetings to promote and provide options for QFly management, including baiting, trapping and fruit sanitation. Achieving strong community meeting attendance is challenging. Some people spoke about derelict orchards and absentee landholders, where owners are not in a position to manage QFly effectively. Grower frustration with unmanaged hosts abounds, for example:

*I had a neighbour who split his block in four, now I have four neighbours where the owners do not live on the land. To get them to spend money to maintain their orchards is almost impossible...I speak to people and they say "Yes, yes, yes" but a month later they still have not done anything.* (Young-Harden grower)

In the focus group growers expressed frustration to a NSW DPI representative over the lack of QFly control enforcement, such as on derelict orchards. He explained that the issue goes beyond NSW DPI to magistrates who are far removed from the QFly issue:

*Here is another inequity. We, as the prosecutors, have to prove to a magistrate say in the Land and Environment Court that this orchard is unmanaged. This guy has to put in just one day of work a year and say “I try to maintain it”, and we are made toothless.*

(NSW DPI representative)

### ***Survey results***

The survey results are summarised in Figure 1. The majority of growers see QFly pressure from towns as a significant risk, with at least 89 percent agreeing in 11 case studies. At the time of the survey the Riverina Fruit Fly Campaign Coordinator had been leading an education campaign for over a year, including media releases, radio talks, a regularly updated Facebook page, newsletters and QFly management workshops. Only 42 per cent of Leeton-Carrathool growers surveyed agreed that the community understood local QFly-related issues. In Young-Harden there had been limited community engagement activities in the period leading up to the survey. In both Leeton-Carrathool and Young-Harden, only 42 per cent and 40 per cent of surveyed growers, respectively, believed that regular education activities would ensure that town residents would adequately manage QFly on their properties. Growers believed that QFly treatments on public land are an effective way of reducing QFly pressure affecting 90 and 80 per cent of Leeton-Carrathool and Young-Harden respondents, respectively. The Central Burnett data reveal some distrust amongst growers about others contributing the recommended amount, with 45 per cent agreeing that others contribute the recommended amount. This influences the decision to contribute of 59 per cent of respondents, who said that they would only contribute if others contributed too. About the same number indicated that they were contributing the recommended amount.

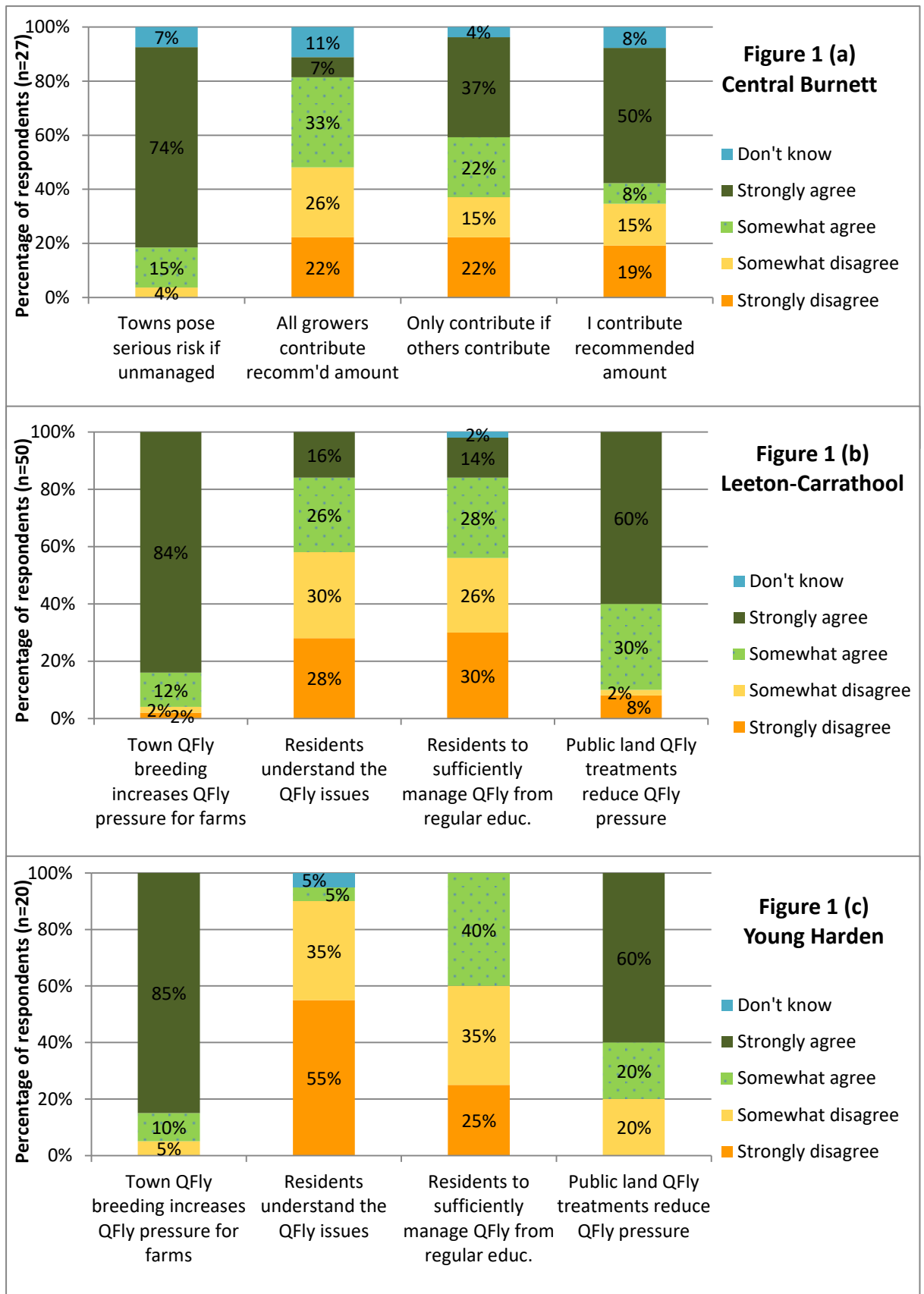


Figure 1. Growers' views about QFly risk from towns across the case studies

## **Discussion**

The promotion of pest management on a collective basis across a region is a sound policy (Marshall et al., 2016; Sindel et al., 2013; Hendrichs et al., 2007), but the case studies show that relying on voluntary approaches alone is challenging. This section explores the four policy instruments identified in Table 3 that could be used to support AWM as part of a “smart regulation” approach.

### ***Voluntary approaches***

Fortunately, most rural towns involve people who value their backyard produce. Arevalo-Vigne et al. (2015) found that 57 percent out of a sample of 606 people in Western Australia are doing something to address MedFly on their land. Education about prudent QFly management practices is likely to tap into their intrinsic motivations to protect their produce and it empowers them to apply effective pest management.

However, the grower survey in the Riverina and Young-Harden shows growers have limited faith in awareness-raising and education, suggesting they might be unlikely to voluntarily invest in them if applied in isolation. Requests to the community to invest time and money—such as on baiting, trapping, netting and/or fruit sanitation—require more skilled negotiations and continued information sharing with them, as opposed to requests that demand little (Larson and Brake, 2011). Reliance on QFly control technologies that are cheap with low maintenance requirements would be more suitable here, such as distributing long-lasting QFly control blocks and traps.

Moreover, a lack of awareness is not the only reason preventing people from diligently managing the pest, as shown by the time-poor 30 acre block owners in the Riverina and absentee landholders in Young-Harden. Some interviewees remarked that messages to backyarders to diligently manage QFly are undermined when a lack of



QFly management close by is evident, such as on derelict orchards. Grower interviewees who personally requested neighbours to manage QFly had limited success.

In short, reflecting lessons learned elsewhere (Curtis et al., 2014; Sindel et al., 2013), it is unlikely that education and awareness-raising alone will elicit on-going strong community support.

Central Burnett demonstrates that depending on grower voluntary contributions to implement town treatments is likely to be thwarted by free-riding and unmet expectations such as when the AWM program does not deliver the sought-after market access.

### ***Broad-based state regulation***

Some AWM experts recommend an enforceable regulatory framework to overcome the issue of risk contributors failing to understand the importance of cooperation (Hendrichs et al., 2007). However, the Riverina's Plant Diseases Order illustrates that issuing broad-based, "top-down" state legislation requiring all landholders with QFly hosts to manage the pest, is problematic. Enforcement is expensive for resource-constrained state departments; there is a moral dilemma in applying injudicious, blanket enforcement to less-abled community members, and magistrate courts fail to understand the level of QFly control required and so reject prosecuted cases. For serrated tussock management, Sindel et al. (2013) concluded that the use of legislation in isolation deliver sub-optimal results to encourage landholder adoption of recommended practice.

### ***Devolved power***

The lack of power at the local level to address QFly pressure from private land was a key concern, especially in the Riverina and Young-Harden. Two ways of devolving power are evident from this research. First, the state can grant powers that traditionally rest with them to local groups. For example, the HPDBs in Oregon and Washington and the SIR Program Boards in British Columbia have authority to enter private land or to

enforce pest control on problematic land. However, the prospects of such approaches in parts of Australia seem limited. For example, the Management of fruit flies in New South Wales - Policy (issued 22 August 2014) states, “legislation should not be viewed as a management tool to force another individual or organisation to comply with community or producer priorities such as the removal of feral trees or the treatment of unmanaged urban fruit trees” (NSW Trade and Investment, 2014: p2).

Secondly, power can be devolved to enable greater self-determination powers, including clearly defined rights and responsibilities, thereby reflecting values from the public participation rationale (Curtis et al., 2014). The community then resembles a “truer” partner in the context of partnerships and shared responsibility (Barker, 2010). However, there are at least two barriers. The first barrier is that in Australia, legislative and political ownership of NRM is mainly retained within state government (Larson and Brake, 2011). In NSW this is evident from both the Local Land Services (LLS) Act 2013 No. 51, a key mechanism through which shared responsibility for natural resource management is performed, and the Biosecurity Act 2015. In addition, state government legislation also determines local governments’ roles and responsibilities and so renders them dependent on state government (Pini et al., 2007). In the case studies, local governments have no special powers to deal with the QFly, including not being permitted to enter private property for QFly management without the landowner’s permission.

The second barrier is that executing self-determining powers is challenging. Adversarial effects encountered in other NRM situations include conflict, reinforcing prevailing political inequalities, or power grabs by elite groups (Berkes, 2010). Existing grower fragmentation in the Riverina is likely to present a key challenge should self-determining powers be granted to this region. Dyck et al. (2005) found that involving the broader community can open a door for uninformed people to influence the program

that can require considerable program resources to deal with. Implementing sound local engagement processes requires significant skill, adequate resourcing and support (Berkes, 2010; Ribot, 2002). Hence, the devolution of power requires considerable simultaneous investment in networking, capacity building (Morrison and Lane, 2006; Larson and Brake, 2011) and building complementary institutions across scales (Ostrom, 2005).

Specifically, the solution is not simply giving more power to local governments. Since the early 1990s local governments have seen a drastic increase in their roles and responsibilities (Pini et al., 2007) without a commensurate increase in revenues (Morrison and Lane, 2006). All six local government representatives interviewed had reservations about their involvement in QFly management. Reasons included financial, staff capacity and capability constraints; fear of setting a precedent for other issues; and concerns about community hostility to spraying activities. Some spoke about the difficulty of securing cooperation between adjacent councils and the lack of formal directive from higher government levels.

### ***Legislated cost recovery-structures***

A legislated income-stream can facilitate industry and other appropriate local stakeholders to implement on-going pest treatments in QFly risk areas. This approach applies in combination with community awareness activities in both the fruit fly SIT program in parts of South Africa and the Canadian SIR program. Funding can be supplemented by government contributions, such as in South Africa. Grower-funded QFly management in Central Burnett towns resulted in positive community feedback.

However, relying on voluntary contributions is problematic. Grower contributions in Central Burnett are dwindling due to issues with free riders and disappointment that the AWM program has not delivered the anticipated market access. Several Riverina

interviewees talked about the need for a local mandatory levy-like system. Dyck et al. (2005) reviewed various AWM programs involving SIT and found that financial and in-kind contributions from growers benefiting most needed to be compulsory, otherwise if industry profitability was low, growers would be reluctant to contribute. Contributions from growers alone, such as in Central Burnett, are only feasible if the ratio between the sizes of the contributing grower population and town population allows it. Such arrangements would be difficult if small local industries or large rural centres are involved. In these circumstances there is a strong case to legislate for rural town residents to contribute too, especially as those valuing their backyard produce will also benefit from such program. This is the case in the Canadian SIR program.

## **Conclusion**

This article investigated how suitable is “smart regulation” as an option for managing QFly pressure from land beyond commercial horticulture orchards. In many horticulture regions local industries are dependent on achieving and maintaining wide-spread community support for collective QFly management based on voluntary approaches and it is proving to be difficult. The strengths and weaknesses of four policy mechanisms that could potentially be included in a “smart regulation” approach were explored. The case studies showed that the local social and cultural context for QFly control varies between regions, suggesting there is no “one-size-fits-all” solution to managing QFly-risk beyond commercial horticulture operations. While this work explored a limited number of policy instruments, it is clear that “smart regulation” offers a prudent way forward. This is due to its ability to give legitimacy to the AWM program, overcome the weaknesses of individual policy instruments and its flexibility to tailor approaches to regional circumstances.

More broadly this work shows that “smart regulation” can be an important tool in partnership and shared responsibility contexts where government encourages industry self-reliance, but where industry has limited sway over diffused risk contributors. Complementary policy instruments can make it more feasible for local industries to carry the main implementation burden and considerable cost of local programs by overcoming challenges of voluntary schemes such as apathy and free-riding. Greater devolution of power can increase the array of policy instruments available to Australian local horticulture industries. However, further research is needed to understand the opportunities and constraints around devolving power for issues that are driven primarily by concentrated, private beneficiaries, while risk contributors are diffused. This includes understanding the appropriate role for local governments.

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#### **4.4 Article 4. Creating an enabling environment for industry-driven pest suppression: the case of suppressing Queensland Fruit Fly through area-wide management**

In an era of limited on-ground government support institutional innovation is required to ensure that the QFly management innovation system is designed such that it makes readily available the knowledge, capabilities and resources that local industries need to achieve AWM. AIS thinking is applied to identify how to create an enabling institutional environment that will support local industries in their quest to achieve QFly suppression through AWM. The main blocking mechanisms in the current support system are identified and they guide pinpointing key opportunities for improvement based on a structural-functional analysis (Jacobsson and Bergek, 2011; Wieczorek and Hekkert, 2012; Bergek et al., 2008).

# Creating an enabling environment for industry-driven pest suppression: The case of suppressing Queensland fruit fly through area-wide management



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## ABSTRACT

Increasing concerns about pests call for the development and uptake of innovative pest management approaches. This coincides with many governments pushing for greater industry self-reliance. This paper investigates how to create a more enabling environment for local industries to suppress Queensland fruit fly (QFly) through industry-driven, area-wide management (AWM). This key recommended approach requires high technical capability and is reliant on cooperation between horticulture growers and other risk contributors, such as town residents, with QFly hosts on their properties. Agriculture Innovation Systems thinking and a functional-structural analysis are applied to the current QFly management innovation system to understand how it constrains or facilitates local industries pursuing AWM. This assists with identifying governance interventions that will support local industries to undertake AWM. Data is derived from semi-structured interviews with key informants from stakeholder groups and a grower survey in three regions where AWM has been achieved or is being attempted. Key blocking mechanisms hindering local industries to pursue AWM have been identified as a lack of local capacity; weak connections between local industries and the broader innovation system; lack of AWM investment; and reliance on voluntary cooperation. Suggestions for policy interventions include supporting intermediation; strengthening local capacity and enabling co-regulation.

## 1. Introduction

Concerns about pest and disease incursions are intensifying due to their economic and ecological impacts and it is increasingly recognised that technological advances need to be complemented by sound pest management governance systems (Higgins et al., 2016; Pautasso et al., 2012). A major challenge to horticulture growers in eastern Australia is Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) (QFly) (Clarke et al., 2011). It can infest over 100 hosts (Dominiak and Ekman, 2013), including most of Australia's A\$9 billion horticulture industry (Plant Biosecurity CRC, 2015). QFly management faces several challenges. Cost-cutting state governments require local industries to shoulder a greater burden (Higgins et al., 2016) to drive on-ground QFly management. Two organophosphate insecticides (fenthion and dimethoate) traditionally used to control the pest have recently been restricted (Dominiak and Ekman, 2013).

Area-wide management (AWM) is now a key recommended QFly control strategy (NFFC, 2016) as it can lessen pesticide dependence. It involves coordinated pest management activities implemented over an extended area, often including commercial orchards, towns, peri-urban areas and public land. All landholders can contribute to risk if QFly populations proliferate on their land and wide cooperation is

fundamental to effective AWM (Hendrichs et al., 2007; Vargas et al., 2008). Related QFly management strategies typically involve integrated 'softer' measures, including pest monitoring, bait spraying, orchard sanitation and sometimes male annihilation technique.

However, examples of successful industry-driven QFly AWM remain limited. A recent study investigated industry-driven QFly AWM from an adaptive co-management perspective. It concluded that local industries need to be embedded in an enabling environment to make industry-driven AWM workable (Kruger, 2016a). That is, social and institutional innovation is needed in the QFly management governance system, alongside technical innovation, to facilitate successful industry-driven AWM.

This resonates with agricultural innovation systems (AIS) thinking that sees innovation requiring co-evolution of technical, social and institutional aspects (Hekkert et al., 2007; Kilelu et al., 2013; Klerkx et al., 2012b). Here, growers are seen as an integral part of the innovation system (IS), as opposed the traditional technology-transfer view that sees them as 'adopters' of technologies developed elsewhere (Klerkx et al., 2012b).

The key research questions are: What are the main constraints to an enabling environment for industry-driven AWM implementation to achieve QFly suppression and how can these be mitigated? This work

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argues that local industries are the entrepreneurs in the IS that supports QFly management in Australia. If an IS does not produce entrepreneurs and/or support them, then its functioning is likely suboptimal as a well-functioning IS will create conditions that make entrepreneurial activities flourish (Hekkert et al., 2007; Negro et al., 2007).

This study applies a structural-functional analysis (Bergek et al., 2008; Jacobsson and Bergek, 2011; Wieczorek and Hekkert, 2012) from AIS thinking to describe, analyse and diagnose the constraints to the enabling environment and ways to address them. This paper makes two key contributions by: (i) assisting in overcoming the 'technocratic thinking' in biosecurity (Maye et al., 2012), including the lack of systems-oriented approaches to innovation in crop protection literature (Schut et al., 2014); and (ii) extending the use of structural-functional analyses in AISs which currently predominantly focus on knowledge fields (such as progress in a country's or industry's overall ISs), to exploring the promotion of an innovative product, here QFly AWM.

The next section describes the IS that supports QFly management in Australia, followed by a literature review and methods applied during this research. The results and analysis section contains a functional-structural analysis to identify blocking mechanisms. The discussion section includes recommendations for policy interventions.

### 1.1. Fruit fly AWM in Australia

Fruit fly AWM programs started in Australia to deal with exotic incursions, including the 1995 eradication of papaya fruit fly in Queensland. It is applied to maintain fruit fly area-freedom in high-value horticulture production areas in New South Wales (NSW), Victoria and South Australia to support market access (Lloyd, 2007). Most notable is the fruit fly exclusion zone that started in 1996 and the associated QFly population suppression in the surrounding buffer zones (Dominiak and Daniels, 2012). Whilst several changes occurred over the years, these initiatives involve partnership arrangements between government and industry. The first AWM program in a QFly endemic area was introduced in Central Burnett, Queensland, in 2003. It has been industry-driven since July 2007 (Lloyd, 2007). This paper focuses on AWM for QFly suppression rather than QFly eradication or AWM for market access, and is based in the states of NSW and Queensland.

The promotion of AWM is embedded in Australia's fruit fly management governance system, which thus can be considered a type of biosecurity management system (Cook et al., 2010; Oude Lansink et al., 2016, in press; Pautasso et al., 2012). Following Schut et al. (2015), innovation in such biosecurity management systems can be approached from an IS perspective. The unit of analysis is how the current QFly management IS constrains or assists local industries to implement industry-driven AWM for QFly suppression. Such knowledge is valuable to identify governance interventions that will support local industries to undertake AWM. This IS is summarised below to set the scene, whilst Section 4 (Results and analysis) provides more detail.

The QFly management IS is spread across a federated system involving delegated people who are responsible for supporting QFly management. The Australian Government oversees international trade matters impacted by QFly (outside the scope of this paper), whilst state/territory governments are responsible for providing support for QFly suppression—including research activities—and domestic market access affected by QFly. Increasingly local governments are expected to support local industries with implementing QFly AWM (NFFC, 2016). Various public and private research organisations conduct QFly-related research.

A representative body takes carriage of coordinating QFly management governance. The National Fruit Fly Strategy Advisory Committee (NFFSAC) was launched in May 2014 and became the National Fruit Fly Council (NFFC) in October 2015 (during the field-work period). Whilst NFFSAC involved predominantly government representation, NFFC involves broader representation, including some growers.

Central to Australian fruit fly management governance are three documents that were developed with government, industry and research community input, and they promote AWM implementation:

- the National Fruit Fly Strategy (NFFS) (PHA, 2008)
- the National Fruit Fly Strategy Implementation Action Plan (NFFS Implementation Committee, 2010)
- National Fruit Fly Research, Development and Extension Plan (Plant Biosecurity CRC, 2015)

AWM implementation typically involves multiple players, especially when these programs are initiated, including growers, local government, state government, crop consultants and researchers.

Considerable research investment exists predominantly to develop better QFly management technologies. Many of them will perform best if applied in an AWM context, most notably sterile insect technique (SIT), a form of insect reproduction control.

### 2. Literature review

In response to Australia's centralised biosecurity governance system, Cook et al. (2010) proposes greater adaptive management via a poly-centric governance approach. Poly-centric resource management enables local resource management programs to tap into local knowledge, devise locally-tailored rules, encourage local learning and lower enforcement costs. This requires programs to be nested in supportive higher level governance systems (Ostrom, 2005).

Structural change in plant biosecurity is increasingly advocated, including the need for farmers and others to influence plant health policies (Pautasso et al., 2012). Combined public and private management strategies tailored to different stakeholders' needs across levels promise better outcomes than the prevailing quest for 'one-size-fits-all' solutions to solve complex biosecurity issues (Oude Lansink et al., 2016, in press). QFly AWM provides a prime example of a complex biosecurity issue, as AWM seldom represents an 'one-size-fits-all' solution for all local horticultural industries (Kruger, 2016b).

However, Australia's agriculture innovation policies tend to focus on the national scale with a high dependence on 'science knowledge' assuming that inventions will diffuse to end-users such as farmers (Nettle et al., 2013). Yet, technologies developed in isolation from intended end-users are often not adopted (Hunt et al., 2014; Kebebe et al., 2015). AIS

thinking promotes a balance between developing new technical inventions and new ways of organising, comprising a wide range of players involved in innovating, learning and change (Klerks et al., 2012b). Hence in the context of poly-centric governance approaches, this includes finding ways that ensure local programs are embedded in an enabling environment (Ostrom, 2005). This means local industries are seen as part of an IS, rather than 'at the end of the line'. Here they are entrepreneurs, where a well-functioning IS will support entrepreneurs in their endeavours to capitalise on new opportunities (Hekkert et al., 2007; Negro et al., 2007). Social learning amongst key IS players from entrepreneurial experimentation is essential to reduce uncertainty in the system. Without entrepreneurial activity an IS will stagnate (Bergek et al., 2008).

Kruger (2016a) stresses the importance of social learning amongst diverse players to ensure AWM programs are designed to fit the local context and the shared objectives of those involved. Information brokering is key in ensuring information is effectively relayed between growers and other parties.

However, ISs can be plagued by systemic problems, that is, 'factors that negatively influence the direction and speed of innovation processes and hinder the development and functioning of ISs' (Wieczorek and Hekkert, 2012, p.79). A systemic problem that has received considerable attention in AIS literature is a lack of intermediation or knowledge brokering, particularly in systems that are 'technocratic' oriented. The importance of intermediation is easily overlooked as it is often invisible

and hard to measure (Klerkx and Leeuwis, 2009; Meyer, 2010). Effective intermediation connects different players by fulfilling key boundary-spanning functions (Klerkx and Leeuwis, 2009; Klerkx et al., 2012a):

- *demand articulation* - including assisting local industries with finding a shared vision to identify their technology, knowledge, funding, and policy needs (Klerkx and Leeuwis, 2009; Meyer, 2010)
- *network establishment* - including local horizontal networks and vertical networks with policy-makers and researchers (Klerkx et al., 2012a; Meyer, 2010)
- *information translation* - to connect 'external' information with the local context and growers' existing knowledge in language that growers find useful (Klerkx et al., 2012a). Likewise, local issues are 'translated' to other IS players to inform their decision-making (Klerkx and Leeuwis, 2009; Meyer, 2010)
- *innovation process management* - working towards better arrangements in the multi-actor network, including facilitating cooperation and learning (Klerkx and Leeuwis, 2009).

## 2.2. Theoretical approach

This paper applies a functional-structural analysis as a heuristic tool to determine how the overall functioning of the fruit fly management IS impacts on the performance of entrepreneurial activity in the form of industry-driven AWM.

The functional component captures all processes that are important for well-performing ISs and that will contribute to making entrepreneurial activities thrive (Hekkert et al., 2007; Negro et al., 2007). These functions are listed below, including how they are interpreted in the context of this study:

- *F1. Entrepreneurial activities* - arranging new knowledge and networks into initiatives, including taking risks. Local industries are motivated and positioned to tap into relevant networks and knowledge to achieve AWM.
- *F2. Knowledge development* - learning can come from formal research, expertise elsewhere or learning-by-doing. Information is produced that is most helpful for local industries to achieve AWM.
- *F3. Knowledge diffusion* - multi-directional information flow encourages learning by interacting with others and by applying certain technologies or approaches. The governance system learns from on-ground experience. All available knowledge that can assist local industries to achieve AWM is readily accessible to them and strong feedback loops exist to the higher-level governance system.
- *F4. Guidance of search* - this involves stakeholders' vision that gives direction to the innovation process, including increasing the clarity of what technology users require. Locally growers need to agree on common objectives, a shared vision, for AWM (including what level of suppression, where and when) and at the governance level stakeholders are committed to supporting AWM.
- *F5. Market formation* - creating markets for products produced in new ways. AWM will support access to markets that require assurances about effective QFly management and provide a cost-effective way to maintain existing markets.
- *F6. Mobilisation of resources* - comprising human and financial capital. Local industries have reasonable access to the resources needed to achieve and maintain AWM.
- *F7. Creation of legitimacy* - resistance to new technologies and approaches need to be surmounted. The governance system instils trust amongst local industries that it will deliver the needed support and growers welcome AWM as an attainable and cost-effective strategy.

The structural components make it possible for the system to function (Kebebe et al., 2015; Wiecek and Hekkert, 2012) and they

comprise (Jacobsson and Bergek, 2011; Turner et al., 2016; Wiecek and Hekkert, 2012):

- *Actors* - individuals, groups, organisations, committees and other stakeholders that fulfil certain roles or whose cooperation is needed.
- *Interactions* - networks, relationships and individual contacts.
- *Institutions* - including hard (legislation and regulations) and soft (norms, customs, ways of conduct and expectations) conventions.
- *Infrastructure* - comprising physical (existing technology and products); knowledge (expertise, research, development and extension, and strategic know-how); and financial (grants, subsidies, levy-based systems and other financial approaches) arrangements.

Functional-structural analyses of ISs take different forms, yet at their core is a commitment to analyse the above structural components and functions in order to identify systemic problems and policy interventions to overcome them (e.g. Bergek et al., 2008; Turner et al., 2016; Wiecek and Hekkert, 2012).

Systemic problems relate to the presence/absence or the quality the structural components, or elements thereof. Systemic problems can often be grouped into underlying blocking mechanisms to aid the identification of policy interventions (Turner et al., 2016).

Until recently, there was limited application of a functionalist view to AISs (Klerkx et al., 2012b), but now several studies have emerged, specifically as functional-structural analyses. Bergek et al. (2008) posit that a functionalist view can be applied to either a product or a knowledge field. Most functional-structural analyses to date focus on a knowledge field. For example, Kebebe et al. (2015) use the approach to investigate dairy development in Ethiopia; and Turner et al. (2016) explore co-innovation in New Zealand's AIS. This study broadens the application of functional-structural analysis in AISs by applying it to a product in the form of AWM.

## 3. Methods

This article forms part of a larger project investigating the social and institutional aspects of industry-driven AWM. Preceding research focused on how the chances of successful industry-driven AWM can be maximised at the local level by exploring three case studies. A key finding was that local industries need to be embedded in an enabling environment to make AWM workable (Kruger, 2016a, 2016b). Subsequently, the key research questions here are: What are the main constraints to an enabling environment for industry-driven AWM implementation to achieve QFly suppression and how can these be mitigated? An underlying aim of this paper is to provide practical insights into industry-driven collective pest management.

The research presented here involved an inductive-deductive interplay between using and developing theory (Eisenhardt and Graebner, 2007). Key components of the functional-structural analysis approach proposed by Bergek et al. (2008) and Wiecek and Hekkert (2012) were selected during the data collection as it captures key themes that were emerging from the data. It illustrates that successful innovation that results in on-ground progress, requires fulfilling more functions than investment in formal knowledge and technology creation that are transferred to industry. An enabling environment for AWM adoption needs all innovation functions to be supported.

An interpretivist theoretical perspective (Denzin and Lincoln, 2000) was applied to understand the real-life experiences of people working in the QFly management IS and how the system operates in reality. It involved in-depth semi-structured interviews. Results were complemented with findings from literature and a grower survey. Benefits of this approach are that it likely captured depth and breadth of information that would have been missed if a more structured approach was applied, such as proposed by Wiecek and Hekkert (2012) and Bergek et al. (2008). A limitation is that a more structured approach might have elicited some information overlooked here as interviewees

Table 1 Background and number of interviewees.

State government <sup>a</sup> - QFly researcher	7
State government <sup>a</sup> - policy	6
State government <sup>a</sup> - industry support	4
State government <sup>a</sup> - operational management	1
Australian government - policy	3
University sector	2
Industry body	7
Local industry	2
Local government <sup>b</sup>	1
Consultant	3

<sup>a</sup> NSW and Queensland only.<sup>b</sup> Five additional local government representatives were interviewed during the case study fieldwork.

did not think from an AIS perspective.

### 3.1. Semi-structured interviews

Thirty-three people working in the QFly management IS (see Table 1) participated in semi-structured interviews during mid-2015. Purposive sampling was applied, which started with choosing interviewees based on their relevant positions (Denscombe, 2014). Later 'snow-ball' sampling was also used (Noy, 2008) including to explore key emerging issues in more detail. One interviewer conducted all interviews, which had an average duration of one hour. Interviewees were asked about their current roles, how they support local industries with QFly management, what barriers they face in this context and how they believe local industries can secure the support they need. Specific questions relating to their roles and experiences were also explored. Interviews were audio-recorded and transcribed verbatim.

### 3.2. Literature review

Various bodies of literature were consulted during the research to better understand emerging themes, provide context to the research and connect the research with existing literature. Academic literature consulted included those relating to AWM; and agricultural research, development and extension, including AIS. QFly-related policy and strategic documents were also reviewed (e.g. PHA, 2008, 2012; Plant Biosecurity CRC, 2015).

### 3.3. Grower survey

A key aim of the survey was to understand how growers perceive key stakeholder groups. For example, it explored to what extent growers trust that groups will provide the needed support. Trust was interpreted as a function of competence ('know how to' and 'able to') and willingness ('want to') of others to cooperate (Graham, 2014). Growers were asked to rate (strongly agree, somewhat agree, somewhat disagree, strongly disagree or 'don't know') statements relating to the perceived competence and willingness of different stakeholder groups. It was conducted in the three case study areas (see Table 2) towards the end of 2015. Grower contact details were obtained from local grower associations or management groups. Most responses were received electronically through SurveyGizmo, with some submitting hardcopies or completing it over the phone with a researcher. The Riverina case study involves five local government areas (LGAs). Limited fieldwork resources allowed two LGAs only to be surveyed, that is, Leeton and Carrathool, based on the preference of the local management group.

### 3.4. Analysis

Interview data was analysed using NVivo 10. Coding involved an

iterative process of constant checking and refining codes and emerging themes as new data came in. Initially coding ('open coding') was based around stakeholder groups. Nodes on key themes were added over time as relationships between codes became clear ('axial coding') (Denscombe, 2014). Eventually, key themes and sub-themes were assigned to the different innovation functions and structural components. For example, as issues regarding funding AWM programs were spread across different stakeholder groups a new node called 'AWM Funding' was created. It was later refined to sub-nodes 'Unfavourable funding conditions' and 'Other funding challenges'. These were later coded to 'F6. Resource mobilisation' and 'Institutions'. When the innovation functions and structural components were introduced, all transcripts were reviewed again to ensure nothing was overlooked. Literature and survey findings were added to complement the interview themes.

### 3.5. Limitations

As QFly management governance is undergoing rapid change, interviewees' opinions might not reflect most recent evolutions. Important developments occurred during the fieldwork (e.g. the NFFC and large research investments were announced) and meeting minutes of key governance bodies were not available to this study. As AWM is often instigated to support market access, another article (Kruger, under review) focuses on supporting the trade aspects of AWM.

## 4. Results and analysis

This section starts with an analysis of the structural components of the QFly management IS followed by the functional-structural analysis and identification of the key blocking mechanisms hindering the innovation process.

### 4.1. Structural analysis

The findings are primarily drawn from the interviews unless indicated otherwise. Overall, interviewees were keen to see progress with the QFly management cause and many felt constrained in the contributions they were able to make.

#### 4.1.1. Actors

The Australian Government has limited direct involvement in QFly suppression as it is mainly responsible for offshore and border biosecurity issues (Cook et al., 2010). State governments are still the major players in guiding local industries, but they increasingly focus on assisting with supporting trade rather than carrying-out on-ground QFly suppression. State governments have experienced ongoing cuts to biosecurity resources and staff (Higgins et al., 2016), causing considerable decline in scientific expertise and applied research (Hunt et al., 2014). Government fruit fly teams are getting smaller due to decreasing budgets. Where some public extension officers still exist, they cover large regions and wide-ranging issues. State governments are key producers of QFly management information, including brochures and on-line information.

Whilst generally sympathetic to the QFly cause, local governments' involvement is overall limited, with some exceptions. Respondents pointed to barriers like lack of resources and suitably trained staff; no clear directive or resources from state or federal government; and fear of setting a precedent for other industries and/or issues; and competing priorities. Since the early 1990s Australian local governments have seen a drastic increase in their roles and responsibilities without commensurate increases in revenues (Morrison and Lane, 2006). Where local governments are supportive, their involvement often follows extensive and persistent lobbying by growers.

Plant Health Australia (PHA) facilitates higher level government-industry fruit fly partnerships in Australia. Horticulture Innovation Australia Limited (HIAL), a research and development corporation, is a



Table 2 Growers survey.

Central Burnett (QLD)	Young Harden (NSW)	Leeton & Carrathool (NSW)
No. of respondents/total population 28/40	20/28	50/98
Response rate 70%	63%	51%
Main crop Citrus	Cherries	Citrus
Background (Kruger, 2016a)		
- Successful industry-driven AWM since 2003	- Working towards AWM	- Working towards AWM
- Endemic QFly region	- Traditionally low QFly-prevalence, with higher pressure during some years	- Previously QFly-free but increased pest pressure since recent years
- Homogenous industry, small towns and high employment of local crop consultants facilitates AWM	- Market access drives QFly-management. Little cherry production losses from QFly	- Strong on-ground government support ended July 2013
- Local management group, including crop consultants, sustains AWM	- Medium-sized towns	- Large diversified horticulture industry, some large towns
	- Local management group drives QFly control with local government support	- Local management group drives QFly control with local QFly coordinator support

key funder of QFly-related research and on-ground initiatives. HIAL administers the industry research and development levies, which the Australian Government matches dollar-for-dollar. Different other public and private research bodies, such as state governments, the Plant Biosecurity Cooperative Research Centre (PBCRC) and universities, also invest in QFly-related research, including several collaborations. Australian universities, which are often seen as key candidates to fill the research supply gap, are increasingly conducting QFly research. However, they generally have a strategic rather than an in-field focus and lack extension capacities.

Researchers from both state government and universities spoke about being fully allocated to their research responsibilities with little time to interact meaningfully with growers. Some experience an unspoken expectation that they will engage with growers and make trade-offs between career benefits, such as publishing and attending conferences, and interacting with growers.

Whilst peak industry bodies differ in many respects, generally speaking they do not have the resources to become involved in local AWM attempts in an on-going capacity, but can assist in providing generic QFly management information and suggesting QFly experts.

Growers are a highly diversified group, including regarding on-farm objectives and attitudes to change. Interviewees' comments confirmed the preceding research's finding that realising local grower cooperation and engaging sources of support can involve high transaction costs. Achieving a local shared vision is challenging, especially when on-farm objectives are heterogeneous (Kruger, 2016b). Similar to the dairy industry program teams describe by Nettle et al. (2013), typically growers will instigate a local QFly or pest management group with other key stakeholders, such as local and state government representatives, that provide a forum for discussing the local QFly situation and how to address it. Some interviewees said that growers are often amazed what they can achieve when they take control and work together. Blaming others, such as other landowners or town residents, for QFly problems hinders ownership and positive action.

Several interviewees alluded to growers needing to accept that change in how QFly management will be dealt with is inevitable. Growers need some affluence or access to capital to work towards AWM to set-up and run the system, and risks are likely to be involved. AWM requires considerable investment, including for management, community engagement and collecting baseline information (Hendrichs et al., 2007). Many horticulture industries face low profitability, which renders many growers risk-averse.

Interviewees pointed to local industries' learning needs that extend beyond implementing QFly practices. These comprise related concepts and practices, e.g. probability, risk management, the roles and responsibility of different stakeholder organisations, effective

stakeholder engagement and basic research concepts for their own experimentation. Considerable variation exists between regions in the level of private crop consultant involvement in QFly management. Seventy-nine per cent of Central Burnett growers employ consultants, with only 30% each in both Young Harden and Leeton and Carrathool. There was some hesitation about the involvement of researchers and consultants from chemical companies, as growers easily perceive them as being driven by commercial interest. Moreover, risk contributors not economically affected by QFly are unlikely to invest in consultancy services to address the pest.

#### 4.1.2. Interaction

The survey shows most growers see a strong role for government to support them in managing QFly. Over three-quarters in all three case studies (77% in Central Burnett, 80% in Young Harden and 82% in Leeton and Carrathool) believe government and industry together need to oversee on-ground QFly management.

**4.1.2.1. Information diffusion.** Similar to the broader decline in agriculture scientific expertise (Hunt et al., 2014), the number of specialists to whom growers, private consultants and others can refer for detailed QFly questions are decreasing. Recent increased investment in producing new QFly experts as part of the research investments was welcomed.

Interviewees emphasised the importance of face-to-face and individual interaction with growers rather than depending upon 'one-size-fits-all' information, such as print materials and websites. Communication through trusted individuals is far more effective than through less-known external people (Kruger, 2016a). Growers prefer practical information, including a list of things to do and physical demonstrations, e.g. farm walks, demonstration plots and field days. Some mentioned that the policy and research community tend to assume certain levels of grower knowledge but in practice this varies.

The survey shows key information sources vary between regions and confirms the importance of individual interaction. In Central Burnett growers will look for QFly information from private consultants (75%) and fellow growers (43%); in Young Harden these are internet searches (50%) and fellow growers (40%); and in Leeton and Carrathool they are state government officers (44%) and the local QFly coordinator (38%). The lowest proportions of growers (under 12%) will seek information from chemical companies, state government print material and other print material.

Similar to the findings of Hunt et al. (2014), close communication loops between those advising growers, and researchers and policy-makers are lacking. Previously, state government extension staff, researchers and policy-makers interacted within the same organisation

Table 3 The percentage of growers who trust that their fellow growers will manage QFly.

	Central Burnett (n = 28)	Young Harden (n = 20)	Leeton & Carrathool (n = 50)
Percentage of grower respondents who strongly or somewhat agreed			
All full-time growers ... to manage QFly			
know how	85%	55%	56%
are able	68%	40%	60%
want	85%	50%	40%
All part-time growers ... to manage QFly			
know how	32%	15%	44%
are able	22%	15%	36%
want	33%	16%	32%

about QFly. Some pointed to insufficient input from the grassroots in setting research and policy priorities and that the 'science [is] driving the industry' rather than 'industry...driving the science'.

Several suggested locally-based trusted people trained in QFly entomology and management to guide and support local industries with implementing recommended best practice.

*It's not as simple as saying, if you bait spray, bait spray early, then go three weeks post-harvest...It is very much almost orchard-specific, it depends on the timing of their fruit crop and a whole lot of factors...So having somebody there to reassure them and keep them on track, because they can panic very easily and then the panic button will be to spray because that's going to make them feel comfortable that they're not going to lose their crop*  
[State government QFly researcher, 24 July 2015]

4.1.2.2. *Trust in others.* The rating of statements in the grower survey confirms that, although variable between regions, growers have limited trust in fellow growers addressing the QFly issue unless there has been a history of cooperation, as in Central Burnett (see Table 3). There is more trust in full-time than part-time growers. Interviewees see addressing abandoned orchards and gaining support from town residents as most challenging, especially when towns are bigger or less connected with horticulture.

#### 4.1.3. Institutions

4.1.3.1. *State policies.* Queensland has no specific legislation dealing with QFly as the pest is endemic. Most notably for NSW is the *Management of fruit flies in New South Wales - Policy document* (22 August 2014), which outlines stakeholder roles and responsibilities. In short, growers, town residents and other landholders are responsible for implementing QFly management on their land, whereas state government responsibilities revolve largely around QFly-affected trade.

4.1.3.2. *Reliance on voluntary cooperation.* A major challenge is gaining the voluntary support from risk contributors (growers and town residents) who have little incentive to manage QFly (Hendrichs et al., 2007; Kruger, 2016b). Not all risk contributors are interested in AWM and the workload and cost of recommended best practice can overwhelm some. Some interviewees believe that higher level decision-makers take local industries' ability to achieve collective action for granted. Some suggested more enforcement powers are needed to ensure consistent QFly management.

*The other thing that we have a lot of problems with is that many of the jurisdictions don't have legislation to actually enforce area-wide management*

[State government officer, 25 August 2015]

4.1.3.3. *Funding rules.* In the Australian research and development arena co-funding is increasingly a requirement for state government requires a holistic approach

investment (Hunt et al., 2014). Investment from government and HIAL for QFly-related research typically requires grower co-funding. High competition for grower voluntary contributions exists, due to other pressing industry needs. Some felt funding opportunities did not meet local industries' needs as 'we've got to tailor the desire of the industry ... to the goalposts of that funding proposal'.

Current funding conditions are often unfavourable for AWM:

- projects preferred for national levy expenditure comprise those that will benefit the wider industry rather than a specific region
- funding is often too short-term to deliver significant outcomes, thereby jeopardising subsequent funding
- funding availability may focus on a limited number of QFly management elements, often in controlled conditions, whereas AWM
- research that will deliver royalties may be preferred, which can be difficult for AWM.

#### 4.1.4. Infrastructure

4.1.4.1. *Funding.* Several respondents mentioned that a lack of resources severely hampers governance efforts, specifically the implementation of the National Fruit Fly Strategy (PHA, 2008) and its Implementation plan (NFFS Implementation Committee, 2010), and the functioning of the National Fruit Fly Advisory Group more broadly. Recent large investments in fruit fly management include:

- HIAL established a sterile insect technique (SIT) consortium called SITplus worth almost \$AUS 22 million in 2015, including extensive research and the development of a SIT rearing facility. SIT is a form of insect reproduction control.
- An \$AUS20.5 million co-investment in mid-2015 for an Australian Research Council Training Centre for Fruit Fly Biosecurity Innovation at Macquarie University to run over five years and work closely with SITplus.

Whilst SIT was welcomed, several interviewees were concerned that SITplus receives a disproportionate amount of funding, as demand for sterile flies might outstrip supply and SIT can only be used when QFly pressure is low. Areas with endemic or high QFly pressure won't benefit from SIT without other measures reducing QFly pressure first.

Apart from HIAL, external funding sources are limited and there is concern about how AWM programs will be funded over the longer term when start-up funding runs out.

4.1.4.2. *Knowledge production.* Much past QFly research has been done, but not all findings are readily publically accessible. A program is in place to deal with this issue. Someone said 'We don't know what we know'. There is limited formal recognition of growers' on-farm 'hands-on' learning. Sometimes informal relationships between growers and researchers capture this information (Kruger, 2016a).

No clearly documented pathway to achieve AWM exists, as each region is unique. Successful AWM cases cannot be used as blueprints elsewhere, although they can provide valuable insights. The concept of AWM is not well defined in Australia, e.g. differing beliefs exist about whether all risk contributors need to cooperate or whether a critical mass will suffice.

Research gaps include aspects relating to evidence justifying the value of adopting certain practices (e.g. picking-up fallen fruit); QFly behaviour (e.g. what is its natural dispersal distance?) and models that will predict population dynamics in different environments.

4.1.4.3. *Extension.* Disappointment with current extension efforts was a key theme, as was confirmed by a QFly research and development prioritisation project (Metcalfe, 2015). Some felt communicating research findings were 'a bit tacked onto the end of a [research] project through a couple of workshops'; or 'it is the extension components in

Table 4 Functional-structural analysis of creating an enabling environment for industry-driven AWM for QFly suppression (adjusted from Turner et al. (2016)).

Problem description	Structural element	Problem type	Blocking mech.
<b>F1. Entrepreneurial activities</b>			
Many growers are risk-averse, especially when profitability is low	Actor	Capacity <sup>a</sup>	1
Growers blaming others hinders positive action	Actor	Capacity	1
Growers have limited trust that others will cooperate in AWM	Interaction	Quality	4
<b>F2. Knowledge development</b>			
Research gaps remain	Infrastructure	Quality	1
Limited use of growers' on-farm learning	Interaction	Quality	2
	Infrastructure	Quality	
<b>F3. Knowledge diffusion</b>			
Much past QFly research findings not publically available	Institutional	Quality	1, 2
Number of QFly specialists are low	Actors	Presence	2
Limited public extension	Actor	Capacity	1, 2
Private crop consultants involvement limited in several regions	Interaction	Presence	1, 2
Extension not prioritised in research funding proposals	Institutional	Quality	1, 2
Growers' QFly information needs are not met by publically available information	Interaction	Quality	1
Some mixed messages about QFly management	Interaction	Quality	1
	Infrastructure	Quality	
Close two-way interaction loops lack between growers and experts, including researchers	Interaction	Presence	2
	Institutional	Quality	
Insufficient grower input in setting research priorities	Interaction	Presence	2
		Quality	
Some policy-makers may take local industries' ability to achieve collective action for granted	Actor	Capacity	2
	Interaction	Presence	
	Interaction	Quality	2
Limited learning between regions			
<b>F4. Guidance of search</b>			
Achieving a local shared vision is challenging	Interaction	Quality	1
Higher level governance and research circles may be over-optimistic about AWM	Actor	Capacity	2
<b>F5. Market formation<sup>b</sup></b>			
AWM (in systems approach) formally recognised by WTO and IPPC, but low market acceptance	Institutional	Quality	
<b>F6. Resource mobilisation</b>			
State governments have ongoing staff and budget cuts	Actor	Capacity	1, 2, 3
Various barriers hinder local government involvement	Actor	Presence	1, 4
		Capacity	
Researchers have limited time to support local industries	Actor	Capacity	1, 2
Peak industry bodies lack resources to provide close, on-going support	Actor	Capacity	1, 2, 3
Several horticulture industries face low profitability	Actor	Capacity	1, 3
Funding conditions not favourable for AWM	Institutional	Quality	3
Limited funding sources	Infrastructure	Quality	3
<b>F7. Creation of legitimacy</b>			
Some growers resist change	Actor	Capacity	1
Lack of enforcement mechanisms	Institutional	Presence	4
Guidance lacking on how to implement AWM	Infrastructure	Quality	2

<sup>a</sup> The quality of actors is referred to as capacity (Wieczorek and Heldert, 2012).

<sup>b</sup> This is an oversimplification of the market formation aspects. This multi-faceted, multi-level issue is explored in another article (under review).

research projects that first get 'dropped out' when savings are to be made'. Some would like to see 'best practice' for extension, not only for conducting scientific research.

Mixed messages exist about QFly management resulting from a combination of imperfect knowledge, varying circumstances (e.g. different crops, climates and farm sizes) and different expert opinions.

#### 4.2. The functional-structural analysis

In Table 4, key barriers from the structural analysis are allocated to the different innovation functions to outline how they affect the dynamics of the QFly management IS and its support for entrepreneurial activity. The problems identified in the above structural analysis have been clustered into the following four blocking mechanisms (Bergek et al., 2008; Turner et al., 2016) that guide the identification of policy interventions in Section 5 Discussion:

1. Lack of local capacity – this includes local barriers to achieving AWM, including the difficulty of achieving a shared vision and collective action, unmet information needs and resistance to change. It is closely related to blocking mechanism No. 2.
2. Local industries and the broader IS are weakly connected – including that grower input and experience insufficiently influence

other players; some higher level stakeholders may be overoptimistic about AWM; and research findings and guidance are often inaccessible to growers.

3. Lack of AWM investment – key challenges include low industry profitability, government budget cuts, unfavourable funding conditions and little long-term resourcing opportunities.
4. Reliance on voluntary cooperation – including the difficulty to achieve collective action amongst risk contributors to address QFly; secure support from local governments; and obtain grower investment in AWM.

#### 5. Discussion

Like many other ISs, the knowledge production is the strongest function (Jacobsson and Bergek, 2011) in the QFly management IS evident from the high research investment and past volumes of research produced. Whilst these investments are much welcomed, there is a danger—following biosecurity's strong positivist 'technocratic' thinking (Maye et al., 2012)—that initiatives such as AWM remains trapped in technology-transfer thinking. The fact that many interviewees spoke about the lack of effective extension, suggests that such thinking features still strong amongst people working in the QFly management IS.

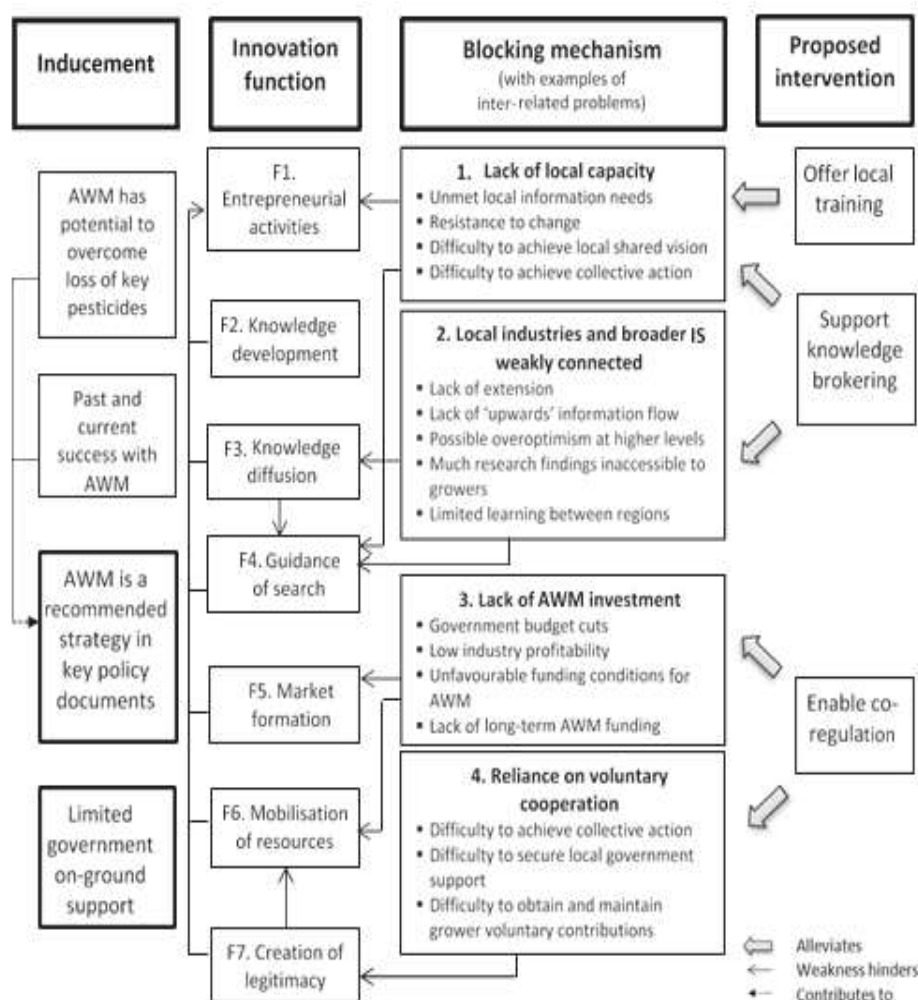


Fig. 1. An overview of the main blocking pathways and entry points for proposed interventions (adapted from Bergek et al. (2008))

This paper shows that an enabling environment for AWM implementation requires more than 'best practice extension', but investment in all innovation functions. A weak connection between local industries and broader IS contributes to poor knowledge diffusion, which results in a lack of local capacity. Regional variability further highlights the importance of a more constructivist approach based on local learning processes and a shared local vision, of which the latter can be difficult to achieve. The reliance on voluntary approaches to secure cooperation from risk contributors and local governments erodes the legitimacy of AWM at the local level. This, together with low profitability, uncertain market benefits and the complexity of AWM, undermine growers' willingness to invest in AWM. These factors can ultimately jeopardise research investments if left unaddressed by the QFly management governance system.

Based on the blocking mechanisms, three policy interventions are suggested, not as an exhaustive list of solutions, but a start to alleviate key pressure points. Fig. 1 provides an overview of the policy interventions' impact on the broader IS.

#### (a) Support knowledge brokering and intermediation

There is a need to strengthen the boundary-spanning functions outlined in Section 2 (Literature review). The National Fruit Fly Research, Development and Extension Plan recommends regionally-based professionals to be intermediaries. Whilst not the best option for every

horticulture region (Metcalf, 2015), the benefit of such individuals is that they can deliberately facilitate multidirectional learning processes where knowledge is co-produced between diverse stakeholders (Klerks and Leeuwis, 2009). The integrated knowledge that intermediaries build over time strengthens demand articulation in the broader innovation and governance system (Meyer, 2010), similar to when state government extension officers worked closely with their policy colleagues. Another promising option to strengthen intermediation between AWM stakeholders is innovation platforms (see for example Kilelu et al., 2013). This is further explored in the related article about AWM for market access (Kruger, under review).

#### (b) Offer local training

Training opportunities for management group members, intermediaries and interested growers can assist local industries to develop AWM programs fit for their local contexts. Training packages can include QFly biology and management options, market access, program management, community and stakeholder engagement and other relevant information needs. Training packages assisted the Australian sugar industry to manage highly-problematic pests on an area-wide basis (Hunt et al., 2012). However, if this is implemented without strengthened intermediation between the local level and the rest of the IS, it will do little to move beyond technology-transfer approaches.

## (c) Enable co-regulation

Complementary government intervention to back-up industry-driven collective action might be a prudent approach in well-functioning polycentric systems (Ostrom, 2005). Tailored to particular circumstances they can combine the strengths of voluntary arrangements whilst compensating for their weaknesses (Bartle and Vass, 2007; Martin and Gunningham, 2014). Such arrangements are evident elsewhere in the world, including legislated income streams, where growers and sometimes other landholders are required by law to contribute to the program. Powers that traditionally rest with state governments, such as the ability to enter backyards to carry out pest management activities, could be granted to local program staff. One such example is the Canadian Sterile Insect Release program for Codling Moth control (Anon., 2011).

## 6. Conclusion

Following restrictions on two key pesticides, local industries are urged to apply AWM to suppress Qfly in an era of limited on-ground government support. Various systemic problems hinder local industries in this pursuit. Clustered into blocking mechanisms they comprise a lack of local capacity; weak connections between local industries and the broader IS; lack of AWM investment; and reliance on voluntary cooperation. Suggestions for policy interventions include supporting intermediation; strengthening local capacity and enabling co-regulation.

The functional-structural analysis provides an effective tool to identify and illustrate how diverse issues influence an IS's functioning and how the IS supports or constrains entrepreneurial activity. This work shows that it offers strong potential for further application to analyse and strengthen the governance of complex biosecurity ISs, including for a particular pest management technology or strategy. Such analyses can support biosecurity governance systems in moving away from the prevailing strong science-production focus (Nettle et al., 2013; Schut et al., 2014). Applying the innovation functions supports the identification of what else can be done beyond developing and transferring new technologies to ensure innovation efforts support entrepreneurs and hence positive on-ground change. However, a limitation of the functional-structural analysis is that it does not capture all factors that will influence uptake. For example, the local social profile of a regional community will also influence the transaction cost, and therefore the feasibility of implementing AWM at the local level (Kruger, 2016b).

Further insights regarding how ISs support entrepreneurs could be gained from a comparative functional-structural analysis between Qfly and other successful AWM programs, such as in Australia's sugar (Hunt et al., 2012) and cotton (Ferguson and Miles, 2002) industries, or the Hawaii fruit fly AWM program (Vargas et al., 2008). Such work would be valuable in further demonstrating the impact value that an IS perspective can offer to strengthening biosecurity.

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#### **4.5 Article 5. Helping local industries help themselves in a multi-level biosecurity world - Dealing with the impact of horticultural pests in the trade arena**

This paper applies the same approach as article 4, but with a key focus on achieving market access using a systems approach involving AWM. Article 4 and 5 are companion documents.





## Research paper

## Helping local industries help themselves in a multi-level biosecurity world – Dealing with the impact of horticultural pests in the trade arena



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## ABSTRACT

In many countries the biosecurity system is under financial strain resulting in an on-going push for shared responsibility and greater industry self-reliance. This occurs in an increasing globalised, multi-level trade context. It raises the question of how the broader support system for local industries can be improved to help industries help themselves. This work relates to systems approaches as a phytosanitary measure in horticulture trade to address pest concerns. Specifically, it investigates how to create an enabling environment for local Australian horticulture industries to pursue systems approaches involving area-wide management (AWM) of Queensland Fruit Fly (QFly). A functional-structural analysis is applied to identify issues that prevent local industries pursuing systems approaches and to suggest ways forward. Primary data is derived from semi-structured interviews with representatives from three levels of government, industry bodies, consultancies and other key groups, complemented by a grower survey in three case study regions. Systems approaches involving AWM comprise a complex domain as it is situated across multiple levels from the local to the international; it involves various dimensions and many rationally-bounded actors. Key blocking mechanisms to local progress include a lack of clear change pathways for local industries; low connectivity between local industries and the innovation system; currently feasibility signals for systems approaches including AWM are weak; and systems approaches are problematic. Ways forward include supporting and initiating innovation platforms, offering domestic and international market access training; and minimising transaction costs to industry.

## 1. Introduction

Pests and diseases have challenged agriculture since humanity started cultivating food. Besides the impacts on productivity, in an increasingly globalised world many pests and diseases now also have significant implications for domestic and international market access for agricultural produce. Recent decades have witnessed an expansion of formal rules and measures at national and international levels to prevent pest and disease spread associated with trade (Maye et al., 2012).

This article explores the promotion of a pest management approach, i.e. area-wide management (AWM). It asks, how can an enabling environment for industry-driven AWM be created in order to support domestic and international market access for Australian horticultural produce? In answering this question, this article generates insights into how the modern-day biosecurity paradigm configures local constraints and opportunities and shapes the possible means to addressing challenges.

Pests often represent complex problems, that is, they involve uncertainty and multiple facets; with actors and institutions situated

across international, national, state, regional, and on-farm levels (Schut et al., 2015). Attempts to strengthen Australian agriculture, including biosecurity, have traditionally relied on technology development and linear technology transfer approaches to farmers (Nettle et al., 2013). The great majority of plant protection literature is based on mono-disciplinary thinking and is technology-oriented (Schut et al., 2014) with some exploring economic impacts (e.g. Yu, 2006). While these have brought tremendous advances, disappointment with outcomes, including a lack of on-ground adoption, is increasingly leading to calls to approach innovation from a holistic systems perspective (Schut et al., 2014). This involves broadening the problem-solving arena to include social and institutional dimensions in order to create an enabling environment for progress to occur (Röling et al., 2012; Klerks et al., 2012).

This paper contributes to filling this void by applying agricultural innovation systems (AIS) thinking that conceptualises innovation as co-evolving technological, social, organisational, and institutional change (Klerks et al., 2010). This paper presents a structural-functional analysis of the Australian innovation system for the management of the pest under consideration, i.e. Queensland fruit fly (*Bactrocera tryoni*

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(Froggatt)). The innovation system here is defined as the operating arrangements that set out how actors and institutions interact and exchange knowledge to develop and spread innovations (Busse et al., 2015). This work argues that a well-functioning innovation system will create conditions that enable entrepreneurial activities to thrive (Hekker et al., 2007; Kruger, 2017).

The paper is organised as follows. The remainder of Section 1 describes the QFly challenge in the modern biosecurity context. Section 2 introduces the structural-functional theoretical framework, while the research methods are outlined in Section 3. Section 4 describes the structural and functional components of the QFly management innovation system. Section 5 explores blocking mechanisms, and policy interventions are suggested in Section 6.

### 1.1. Background

The fruit fly family Tephritidae is one of the world's most significant horticultural pests. The annual global cost is around US\$ 2 billion, including impacts on production, harvesting, packing and marketing (Malavas, 2014). Eastern Australia is confronted by Queensland fruit fly, or QFly. The fly is of considerable concern to Australia's international horticulture trading partners. Most of Australia's fruit and vegetable exports, worth approximately AUS\$1048 million in 2014–15 (Abares, 2015), are susceptible to varying degrees (Plant Biosecurity CRC, 2015).

The challenge recently intensified following restrictions on two key pesticides, fenitrothion and dimethoate, traditionally used to control QFly at relatively low cost through a simple single-treatment approach (Dominiak and Ekman, 2013). A current key recommended strategy to local industries is the application of area-wide management (AWM) (PHA, 2008; Plant Biosecurity CRC, 2015). AWM involves total pest population management by coordinating control strategies across all key pest sources throughout a region (Hendrichs et al., 2007). This allows for the application of softer control techniques for QFly such as protein baits, orchard hygiene, male annihilation technique and sterile insect technique (SIT) (Jessup et al., 2007).

Another benefit of AWM is that it is seen as a good candidate to underpin systems approaches for trade (PHA, 2008; Dominiak and Ekman, 2013). Systems approaches for trade comprise two or more independent pest treatments or measures throughout the supply-chain that collectively reduce pest risk to an acceptable level (PHA, 2008; Jamieson et al., 2013). International trade rules set by the World Trade Organisation (WTO) and the International Plant Protection Convention (IPPC) recognise such approaches as acceptable phytosanitary measures (Dominiak and Ekman, 2013).

This occurs against a national backdrop where Australia's biosecurity governance during recent decades increasingly emphasise shared responsibility and partnerships between government, industry and the broader community. It includes a shift of biosecurity costs and responsibilities from the state to agricultural producers accompanied by cuts to public biosecurity funding (Higgins et al., 2016). It implies that local industries are predominantly responsible for driving initiatives such as AWM and related systems approaches for market access.

The international context involves the WTO and the IPPC advocating free trade whilst promoting a science-based approach in a bid to minimise biosecurity risk (Maye et al., 2012). For example, they oversee the production of globally agreed International Standards for Phytosanitary Measures (ISPMs) to underpin international trade, including several relating to systems approaches, AWM and fruit flies. Australian biosecurity policies and activities are increasingly aligned with international market logics (ibid.).

Hence, in the modern biosecurity paradigm the market dominates and processes of harmonisation and standardisation rooted in scientific expertise stand central (Higgins et al., 2016; Maye et al., 2012). Some call for more "alternative spaces of negotiation" that allows for more flexibility and negotiation (Higgins et al., 2016; Enticott, 2008).

Within the QFly context, these orderings brings about a complex multi-faceted, multi-level innovation system as is outlined in Box 1. There are multiple horticultural crops, geographical and climatic conditions, types and size of horticultural enterprises, and commodity groups differ in how well they are organised. Besides growers, many other actor groups are involved, including different levels of

#### Box 1

The key structural components of the trade-related QFly management arena.

##### Actors

###### International

- WTO and IPPC

###### Australian Government

- Department for Agriculture and Water Resources – responsible for international border biosecurity and trade, including conducting negotiations for overseas trade

###### National

- State and territory departments responsible for agriculture – oversee onshore biosecurity and domestic trade
- Plant Health Australia – coordinates government-industry partnerships
- Peak industry bodies – representative bodies for different horticulture commodity groups, including providing some support to QFly-affected industries to facilitate trade
- Horticulture Australia Innovation Limited (HIAL) – a research and development corporation and a key funder of QFly-related on-ground initiatives

###### Local industries

- Local pest/QFly management groups
- Local coordinator (sometimes)
- Growers

*Consultants*

- Crop consultants
- Market access consultants

*Research providers*

- State government departments
- SITplus – an almost \$AUS 22 million initiative since 2014 that includes extensive research
- Centre for Fruit Fly Biosecurity Innovation – established in 2014 at Macquarie University and involves close cooperation with SITplus
- Plant Biosecurity Cooperative Research Centre
- Commonwealth Scientific and Industrial Research Organisation
- Universities
- Australian Bureau of Agricultural and Resource Economics and Sciences
- Private companies/institutes

**Institutions** (main ones only)*International*

- Agreement on the Application of Sanitary and Phytosanitary Measures (the 'SPS Agreement') – is applied by the WTO and IPPC to maintain plant health during international trade
- International Standards for Phytosanitary Measures (ISPMs) – to provide assurances that pest risks are addressed in trade deals

*Domestic*

- Nationally agreed principles and procedures to manage QFly surveillance, trapping, outbreaks and eradication from pest free areas (under review)
- Draft National Fruit Fly strategy (2008) and National Fruit Fly Strategy Implementation Action Plan (2010) – include strategies to progress AWM of QFly and related trade
- Interstate Certification Assurance (ICA) scheme – domestic trade protocols, many commodity-specific and relating to fruit fly, with some being region-specific
- the National Fruit Fly Research, Development and Extension Plan – released in 2015, including recommendations relating to AWM and trade

**Infrastructure***Funding*

- Growers
- HIAL – administers grower levies, which are co-funded by government
- State and territory governments
- Australian Government
- Universities

*Knowledge*

- Fruit fly body of knowledge – Repository of fruit fly related documents and publications
- Research providers listed above

*Physical*

- QFly trapping networks in pest free areas
- QFly management technologies
- SITplus' SIT rearing facility

**Interactions** (main forums only)

- Plant Health Committee – a high-level interstate committee that provides strategic scientific and policy advice related to plant biosecurity to the Australian Government
- National Fruit Fly Council – government and industry committee that provides national leadership and coordination to manage fruit fly in Australia
- SITplus consortium
- Subcommittee on Domestic Quarantine and Market Access – an interstate committee that develops domestic market access conditions, including ICAs
- HIAL's Trade Assessments Panel (TAP) – an advisory group supporting HIAL providing advice to the Australian Government about prioritising market access applications requiring protocols



government, various groups within government departments, industry bodies, diverse public and private research providers and consultancy services.

Diverse actors have wide-ranging interests (Röling et al., 2012) and are rationally-bounded, that is, their decision-making is limited by the information, resources and time available to them. Hence, multiple and sometimes contested logics exist amongst actors about how biosecurity and aspects thereof should be ordered (Higgins et al., 2016).

## 2. Analytical framework

The key research question is how can an enabling environment for industry-driven fruit fly AWM be created in order to support domestic or international market access for Australian horticultural produce? This work is a corollary of earlier research about the social and institutional aspects of local industries pursuing industry-driven AWM, involving three case studies of where AWM has been implemented or is attempted. A key finding was that local industries need help to help themselves through an enabling and supportive institutional environment (Kruger, 2016).

### 2.1. AIS and functional-structural analysis

AIS thinking acknowledges that innovation requires more than techno-centric approaches (Klerkx and Leeuwis, 2008; Klerkx and Nettle, 2013). Innovation that leads to on-ground change tends to flow from improved distribution of existing knowledge by establishing interaction, collaboration and coordination between different actors representing diverse organisations and responsibilities. This leads to co-production of new knowledge and a shared trajectory that can bring about change (Klerkx and Nettle, 2013). However, connections need to be actively constructed and interactions coordinated (Kilelu et al., 2013).

Hekkert et al. (2007) identified “functions of innovation systems” that represent processes essential to well-performing innovation. This study applies them to determine how the current QFly management innovation system assists and hinders local industries pursuing access to QFly-sensitive markets involving AWM. These functions are:

- F1. Entrepreneurial activities – the presence of actors turning new knowledge and networks into actions. Experimenting means more knowledge is produced about the innovation system’s functioning in different circumstances
- F2. Knowledge development – learning forms the core of innovation, including formal research and knowledge production elsewhere
- F3. Knowledge diffusion – comprising networks of multi-directional information flows involving “learning by interacting” and “learning by using”
- F4. Guidance of the search – the innovation process requires direction to optimise use of limited resources. It can cumulatively come from external influences (e.g. rules or benchmarks) and/or a shared vision between key actors
- F5. Market formation – products produced through new technologies compete with what buyers are used to, hence effort is required to secure buy-in
- F6. Mobilization of resources – including financial and human capital
- F7. Creation of legitimacy – the new technology needs to overcome opposition and resistance to change by becoming part of producers’ prevailing accepted practices

Innovation systems can also be conceptualised based on their structural components. Any weak structural component will compromise the innovation system’s functioning (Kebebe et al., 2015). These typically are (Wieczorek and Hekkert, 2012; Turner et al., 2016):

- Actors – individuals, groups, organisations, businesses, committees and other parties across levels that fulfil certain roles or influence QFly-risk management
- Interactions – the dynamic exchanges between actors
- Institutions (rules) – including (i) hard – legislation, regulations and standards; and (ii) soft – such as norms, customs, ways of conduct and expectations
- Infrastructure – including (i) physical – such as existing technologies and products; (ii) knowledge – expertise, strategic information, research, development and extension; and (iii) financial – subsidies, grants, levy systems and other financial systems

This study involves a combined functional-structural analysis (Turner et al., 2016; Kebebe et al., 2015) to offer a holistic system analysis. The seven functions assist in identifying difficulties preventing progress, which are clustered to identify key blocking mechanisms. The blocking mechanisms assist in the identification of policy interventions (Turner et al., 2016).

## 3. Methods

The research is based on an interpretivist theoretical approach that captured the experiences of actors active in the QFly management innovation system (Denzin and Lincoln, 2000). It involved an inductive-deductive interplay between using and developing theory (Eisenhardt and Graebner, 2007). As such, it was during the data collection phase that the functional-structural analysis approach (Bergek et al., 2008; Wieczorek and Hekkert, 2012) was chosen as it represented a close fit for explaining emerging findings, in particular, it became clear that a combination of factors was slowing progress, rather than a lack of technologies and/or their adoption only.

### 3.1. Data collection

Thirty-three semi-structured interviews were carried-out during mid-2015. Interviewees were initially selected using purposive sampling by approaching actors in relevant roles in stakeholder organisations. This was followed by “snowball” sampling, for example, interviewees suggested other actors that would allow for exploring some themes in greater depth (Denscombe, 2014). Interviewees included representatives from three levels of government, peak industry bodies, universities, industry consultants and local industries. Interview questions included enquiries about their current roles, how they currently supported local industries with QFly-affected market access, barriers faced in providing support and how they believed local industries can go about securing support. Interviews proceeded on average for an hour, were audio-taped and transcribed verbatim. This research focused on New South Wales (NSW) and Queensland, a corollary of the preceding case study research.

In late 2015 growers in the three case study regions were surveyed (Table 1) and results are included to allow for methodological triangulation and increase the findings’ richness (Denscombe, 2014). Local management groups or industry associations provided grower contact lists. Only growers interested in supplying to QFly-sensitive markets were asked market access-related questions. Most growers responded electronically via SurveyGizmo, with some returning hardcopies and others completing the survey with a researcher over the phone. Limited fieldwork resources meant only two of the five local government areas (LGAs) in the Riverina were surveyed. The local management group opted for Leeton and Carrathool. A key survey limitation is small population sizes. A review of available policy and scientific literature was performed, to allow for further method triangulation by providing information on context and to verify findings (Bowen, 2009).



**Table 1**  
Grower survey.

	Central Burnett (Queensland)	Young Harden (NSW)	Leeton & Carrathool (Riverina, NSW)
No. of respondents (response rate)	28 (70%)	20 (63%)	50 (51%)
No. of respondents interested in QFly-sensitive markets	26	12	22
Main crop	Citrus	Cherries	Citrus
Background	<ul style="list-style-type: none"> <li>• Industry-driven AWM since 2003</li> <li>• Achieved access to some domestic markets based on a systems approach (ICA-28)</li> <li>• Overseas export to QFly-sensitive markets requires costly post-harvest treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Export-oriented growers participate in a domestic systems approach protocol trial as forerunner for international trade</li> </ul>	<ul style="list-style-type: none"> <li>• Different initiatives underway in the Riverina to support market access to QFly-sensitive markets.</li> </ul>

### 3.2. Data analysis

Data was analysed in NVivo 10. Findings from the interviews and survey were allocated against the seven functions and the structural components of the structural-functional elements. More details are available in Kruger (2017). A document review assisted in filling in gaps in the structural analysis (see Box 1).

### 3.3. Limitations

This article reports on market access, whereas AWM for QFly suppression is dealt with in separate article using the same methodology (Kruger, 2017). This work presents a snapshot in time of the issues faced within the transitioning field of on-ground QFly management. Interviewees' information might not always have been current in this fast-changing arena. Most recent information, such as meeting minutes of advisory groups, such as the National Fruit Fly Council, was not available to this research.

## 4. Results

This section outlines the functional-structural analysis. The structural analysis is outlined in Box 1; the functional analysis is described below and the structural-functional analysis is summarised in Table 4. Each function's heading below (in bold) states its aspirational interpretation as a benchmark of what each function should achieve in this study's context.

**F1: Entrepreneurial activities – Local industries are empowered to identify and adopt new opportunities. Opportunities are readily available.**

Different forms of entrepreneurial activities were evident. Box 2 provides a prime example of private entrepreneurial, industry-wide activity in the Australian cherry industry. As found elsewhere in Australia's techno-centric innovation context (Nettle et al., 2013), it represents an informal governance system stimulating innovation by engaging with grower target groups and other key actors thereby enabling "routes to change". It reportedly enjoys high grower and government support. Some regions, such as Young-Harden, pursue local-specific opportunities, such as working towards a domestic trade window based on demonstrable low QFly-prevalence during most of the cherry harvest season. Some interviewees pointed out that local industries that are demonstrably proactive, well-organised and who show resolve are more likely to secure support than those less organised.

Key challenges include limited understanding among growers about market access rules. Interviewees spoke about achieving AWM being onerous, especially gaining wide-spread support from all risk contributors, including town residents and peri-urban landholders (Kruger, 2017). Someone mentioned that "you need a lot of ducks lined up" and that "before you can negotiate market access, you need the system... to be up, running, established and working repeatedly". Accessing QFly-sensitive markets places considerable demands for infrastructure investment. For example, orchards, packing houses and storage facilities need to be certified as meeting the necessary requirements. Initiating and running systems approaches and AWM also require extensive data gathering to demonstrate adequate QFly control. Systems are needed to prevent infestation while fruit is being transported. "Back-up" systems, such as cold treatment, are required if the systems approach fails.

Progressing market access requires liaising with many actors, whether it is pursued by a local industry representative, an industry

### Box 2

Working towards better market access options for the Australian cherry industry.

Cherry Growers Australia (CGA) is driving a concerted effort to assist cherry growers to be "export ready". It works closely with the industry's lead research agency, the Tasmanian Institute of Agriculture (TIA) to support growers. A TIA researcher coordinates a project committee with representation from all state associations. The committee ensures local industry needs are linked with opportunities and requirements at higher levels, through a cyclical process of giving and receiving input and feedback from and to regions.

The TIA researcher also coordinates a national extension program that is closely linked to the cherry industry's market access-related biosecurity management program (BMP). Trust-based relationships have been a priority throughout this work.

Consultants develop the BMP by drawing together different forms of knowledge. These include market access rules, varying needs of regions and market access arrangements developed elsewhere, while ensuring the program is aligned with market access systems being developed by state governments. They liaise closely with growers, different state and federal government officials and other relevant actors. The consultants provide a single point of contact for growers about market access issues and form an interface between growers and the Australian Department of Agriculture and Water Resources (DAWR). The consultants and researcher adjust their communication with local industries based on growers' existing knowledge.

There were challenges resulting in transaction costs to industry. These include the consultants needing to spend much time and effort on obtaining historical trapping data from some state governments; getting key decision-makers from different government bodies together to liaise and make joint decisions; liaising with a wide range of actors; and prompting actors to find solutions to challenges the consultants had no control over. Government staff turnover complicated maintaining consistent relationships.



body or a consultant.

Having the right people in the same room at the same time seems to be one of those things that if you can pull that off and start getting the various experts or people who have experience in those fields—or I guess the level of authorization because it is their decision—all talking together, that is most helpful. [Consultant]

Some interviews posited that dealing with QFly could be strengthened through greater institutional harmonisation between states. For example, acceptance of domestic trade protocols as part of the Interstate Certification Assurance (ICA) scheme, across all states, will contribute to clearer and more consistent guidance at the local level.

**F2: Knowledge development – Knowledge is developed that will equip local industries to harness new opportunities and maintain current markets.**

As Box 1 illustrates large investments are made in research projects related to QFly. The National Fruit Fly RD&E plan identifies investment in systems approach-related research for market access as a priority, including both basic science and successful field examples that can be used as exemplars (Plant Biosecurity CRC, 2015).

Key challenges that interviewees identified include information gaps, such as the development of verifiable protocols, including thresholds (e.g. numbers of QFly caught in trap) that would trigger growers to take corrective action. Several spoke about the difficulty of statistically proving how different QFly-control mechanisms combined in a systems approach<sup>1</sup> will deliver a continued pest-free product (Jamieson et al., 2013).

**F3: Knowledge diffusion – All existing information that could assist local industries to achieve and maintain domestic and international market access is readily available to them. Information from the regional level is readily reaching policy-makers.**

Designing a workable systems approach requires holistic input, including combined on-farm, funding, regulatory, market and government perspectives. Some interviewees pointed out that market access protocols that are developed together with local industries are most likely to be used by growers, such as in Central Burnett (Lloyd et al., 2010) and the recent progress made by the cherry industry (Box 2).

Specially appointed state government officers supported local industries in their market access pursuits. While described as “thinly spread” across many regions, they played an important brokerage role in assisting some local industries to develop new trade protocol applications.

The Australian Government’s DAWR is the main holder of expertise about international market access, whereas state governments’ key focus traditionally has been domestic market access. Interviewees talked about the direct contact between state government staff working directly with growers and staff negotiating domestic market access. This assists two-way negotiation between trading partners to ensure protocols are practical to growers and supply chain members, and meet market needs. Such short communication loops are less prevalent for international market access proposals. Here proposals need to be considered by a specially appointed expert group under the auspices of HIAL that recommends to DAWR which proposals need to be pursued for negotiation. There can be a considerable lag between the last industry input and a protocol being negotiated. Several interviewees would like to see more opportunity for industry input close to or during international bilateral negotiations. Several export protocols are not utilised in part because growers regard them as impractical or uneconomical to implement. Some pointed out that changing approved protocols requires considerable time, cost and evidence-gathering that diverts resources from opening new markets.

Until recently, DAWR’s communication to growers about international market access was mainly via peak industry bodies and through

information provided on the internet. Some DAWR interviewees mentioned that the need for strengthening direct communication with local industries, states government and consultants has been recognised. The horticultural industries are developing export strategies, with feedback from DAWR, including identifying key knowledge gaps and goals. DAWR has launched initiatives to build state governments’ knowledge of relevant international trade matters. Increasingly domestic trade is modelled on international trade arrangements. Over time successful domestic protocols then build evidence to support international market access applications using the same protocol.

The survey results suggest that growers have high hopes of AWM as part of a systems approach to underpin international trade. The survey asked export-oriented growers to rate to what extent they agree with the statement “An area of low pest prevalence (ALPP) is valuable in negotiating international market access as part of a systems approach.” An ALPP is a formal pest risk mitigation measure and is often underpinned by AWM. Across all respondents, 92 percent (55 out of 60 respondents) agreed, with 75 percent strongly agreeing and 17 percent somewhat agreeing. By contrast, interviewees operating closer to the trade negotiations arena are sceptical about current international acceptance of systems approaches and ALPPs for fruit fly host commodities (see F5: Market formation).

Key challenges include the difficulty of maintaining strong linkages between DAWR and local industries, including a lack of short communication loops during trade protocol negotiations. Several interviewees want DAWR to work closer with local industries to strengthen local understanding about international market access rules. Some suggested that effective communication between peak industry bodies and all growers cannot always be assumed. Relying on webpages involve challenges, e.g. DAWR lists export-related information on-line, but many growers need help understanding it and some information can only be obtained from trading partners. Governments’ interactions with growers are affected by government staff turnover, resulting in lost nuanced knowledge about their region’s QFly situation and trade opportunities.

Few actors understand the entire system, that is, from the perspectives of QFly entomology, the complexities of on-ground QFly management, developing export protocols and the associated research required, the trade negotiation processes and delivering a consistent product. Someone mentioned that “there are so many bits to it and there are not a lot of people who are knowledgeable about all those things”.

Some interviewees mentioned that actor groups speak “different languages”, for example, entomologists use different terminology than market access staff. Many entomologists and crop consultants have only “passing knowledge” of international plant protection rules. Some growers misinterpret what is feasible in the trade context leading to false expectations, for example, by believing that they can supply anywhere because they have consistently produced QFly-free produce.

National government committees might predominantly focus on meeting international trade obligations and other countries’ requirements.

They’ve [advisory body] got a lot of issues on high priority like area-wide management and systems approaches but I think there’s a lack of understanding of how difficult it actually is to establish some of these systems approaches. [State government official]

As found by Higgins et al. (2016), some interviewees remarked that local industries do not feel listened to, despite persistent lobbying efforts by peak industry bodies. Others pointed to a lack of growers using their agri-political voices. Growers’ limited understanding of the international trade arena means that they can easily underestimate the amount of effort governments and industry bodies invest in securing and maintaining trade.

**F4: Guidance of the search – A clear vision exists at the local and the higher QFly management innovation system levels that AWM and systems approaches are key ways forward and will enjoy commitment and support as long term goals.**

<sup>1</sup> Just before publication of this article, HIAL instigated a project that aims at quantifying the different steps in systems approaches.



**Table 2**  
Growers' trust in their management groups' ability to assist them in overcoming QFly-related market access issues.

The management group...	Central Burnett (n = 26) (Percentage of grower respondents who strongly or somewhat agreed)	Young Harden (n = 12)	Leeton & Carrathool (n = 22)
...understands our QFly-related issues hindering market access ('know how to')	85%	100%	96%
Strongly agree	77%	92%	73%
Somewhat agree	8%	8%	23%
...is capable of supporting our local industry (including working with the right government people) ('can do')	89%	91%	81%
Strongly agree	54%	58%	36%
Somewhat agree	35%	33%	45%
...is serious about helping our local industry ('want to')	89%	100%	86%
Strongly agree	62%	83%	59%
Somewhat agree	27%	17%	27%

As Box 1 illustrates, all key QFly-related strategic documentation include the promotion of AWM and systems approaches. Yet, they need strong technical and logistical support to operate (Hendrichs et al., 2007). State governments are key players in assisting local industries with systems approaches, with some success and a number of domestic trials underway. A strong theme amongst interviewees was that market access initiatives should start in the regions ("bottom-up"). This includes growers developing a shared vision and making their wishes known to government. Different groups, for example, the then National Fruit Fly Advisory Committee (predecessor of the National Fruit Fly Council) and Cherry Growers Australia (CGA), are developing a toolbox of QFly-management practices that growers can use as part of a systems approach. Local QFly management groups typically form to work with key actors to develop a shared vision and to lead the local industry to strengthened market access (Kruger, 2016). Growers' trust in a management group's ability to capitalise on market access opportunities is essential to achieve local support and co-operation. Trust here can be conceptualised as a function of the ability ("know how to" and "can do") and the willingness ("want to") of the management group to fulfil its functions (Graham, 2014). The survey asked respondents to rate to what extent they agree or disagree with three statements about their local AWM management group based on these functions of trust. Overall trust levels were very high (Table 2). Trust rated least—albeit still high—for the management groups' capability to improve market access. This suggests that respondents are confident that their management groups possess the necessary knowledge about market access and are motivated to work toward this goal, but there is hesitation about whether management groups have established effective interactions with the right government officers. Note that the study did not measure local management groups' actual abilities to fulfil these functions.

Key challenges include that clear guidance lacks on how to initiate AWM and systems approaches. When interviewees were asked how they think local industries can go about it, responses varied considerably. Some believed that local industries' first point of call should be their local government, others thought state government and others growers' peak industry body. Interviewees spoke about relevant ISPMs being vague, lacking the needed detail for clear direction; and limited examples of international systems approaches for fruit flies exist that local industries can draw upon. There is tension between the need for harmonised procedures that will satisfy markets and for AWM programs to be locally adapted.

You need a regional approach...but there needs to be sort of cohesion amongst the regions so that we don't have wildly different schemes going be put forward for market access. [Australian Government representative]

Currently no nationally agreed management principles for ALPPs for fruit flies exist, although discussions with state and federal governments, industry and researchers are ongoing. Attaining a shared vision is challenged in local industries where there is high heterogeneity and/or fragmentation (Kruger, 2017).

**F5: Market formation – Profitable markets are available to local industries based on workable systems approach protocols.**

The ICA system was generally seen as a big success for domestic market access. Some were hopeful that AWM as part of a systems approach could assist in overcoming the need for costly post-harvest QFly treatments for international trade as is the case for some ICAs (Kruger, 2016).

Gaining or improving international market access can be difficult and lengthy processes. Interviewees spoke about countries having different phytosanitary requirements and occasionally some country requirements change. Several interviewees believed politics and protectionism, along with scientific evidence, influence market access decisions. A state government representative pointed out that "you always hope that putting the science forward is going to be enough" but that "there's always an alternative viewpoint that someone can argue...to refute what you're saying".

Key challenges that interviewees identified include that most markets prefer simple single treatments such as the now restricted chemicals, or costly post-harvest treatments. Systems approaches are not well accepted in international trade (Jamieson et al., 2013). An industry body representative mentioned that "we do need to keep exploring [systems approaches] because the pest is not going to go away".

Regional trade protocols involving in-field QFly management measures often require regular pest surveillance data based on monitoring a "trapping grid" across the region. Under international trade rules, government is currently recognised as the only independent monitor. Due to restricted state government funding, accepted third-party monitoring is being discussed. Several interviewees were concerned that the cost to industry to fund such a service could render trade arrangements uneconomical.

Another source of concern was that if Australia desires other countries to accept systems approaches without end-point treatments for Australian export horticulture, Australia needs to be open to accepting similar systems approaches to underpin horticultural imports. Acceding to this could cause a backlash from some Australian horticultural industries.

**F6: Mobilization of resources – Resources are readily available to industries to develop and implement systems approaches and AWM.**

Recent Australian Government funding opportunities, such as the Package Assisting Small Exporters, are opening opportunities for some local industries to pursue systems approach protocol development. However, a key theme was that a lack of investment from both government and industry hampers progress. Interviewees mentioned that clear signals that AWM and systems approaches make economic sense are fundamental for grower buy-in. This is especially true, given Australia's reliance on market-driven approaches with minimal agriculture protection and support (Higgins et al., 2016). Grower investment is further hindered when profitability is low and competing priorities exist for grower funding. Several funding opportunities are unfavourable for AWM (Kruger, 2017). Interviewees mentioned that some state government funding models fully allocate staff time to existing projects so that staff have little time to assist industries with developing new project ideas and funding proposals. Others said that the



**Table 3**  
Percentage of growers who agree that government is supportive in overcoming QFly issues hindering market access.

The state government department responsible for agriculture...	Central Burnett (n = 26) (Percentage of grower respondents who strongly or somewhat agreed)	Young Harden (n = 12)	Leeton & Carrathool (n = 22)
...understands our QFly-related issues ('know how to')	77%	100%	91%
...is capable of supporting our local industry ('can do')	62%	100%	86%
...is serious about helping our local industry ('want to')	53%	100%	77%

The Australian Government department responsible for agriculture...	Central Burnett (n = 26) (Percentage of grower respondents who strongly or somewhat agreed)	Young Harden (n = 12)	Leeton & Carrathool (n = 22)
...understands our QFly-related market access issues ('know how to')	48%	75%	85%
...is capable of supporting our local industry ('can do')	50%	75%	81%
...is serious about helping our local industry ('want to')	27%	50%	48%

ongoing need to monitor and verify that a systems approach's different components are working as intended, makes them expensive to run.

**F7: Creation of legitimacy** – The QFly management innovation system instils trust in growers that it can provide the needed support and that AWM and systems approaches are viable options.

The survey investigated the levels of trust that growers have towards state and federal governments (Table 3). Like others identified (e.g. Higgins et al., 2016), trust in government lacks, except when recent close cooperation occurred, such as in Young Harden where the state department was assisting growers with a domestic systems approach trial. Direct interaction tends to foster mutual trust (Busse et al., 2015). Overall, growers' trust in state governments is higher than in the Australian Government, but it appears most compromised in growers' views about governments' willingness to support them.

Other key challenges include that policy-makers might lose legitimacy when they lack understanding of on-ground challenges. The lack of local-level understanding about the trade arena suggests that many growers do not appreciate the large investments government and industry bodies make to facilitate trade.

## 5. Discussion

The functional-structural analysis presents a snapshot in time. However, it demonstrates that considerable challenges exist—other than technological deficiencies—that prevent QFly AWM as part of a systems approach to become an established trade-supporting measure in Australian horticulture.

**Table 4**  
Summary of the functional-structural analysis of creating an enabling environment for local industries to pursue AWM as part of a systems approach (SA).

Summary of key issues	Structural problem type	Blocking mechanism
<b>F1: Entrepreneurial activities</b> Growers have limited understanding of market access rules SAs including AWM require developing and implementing extensive systems Grower voice regarded weak in higher level forums Progressing market access can require liaising with and joint decision-making between diverse actors	Actor Interaction Institutional Infrastructure Actor Interaction Interaction	Lack of clear market access pathways Lack of clear market access pathways Low system connectivity Low system connectivity Lack of market access pathways
<b>F2: Knowledge development</b> Various information gaps remain Difficult to statistically prove the effectiveness of SAs	Infrastructure Institutional	Lack of market access pathways SAs problematic
<b>F3: Knowledge diffusion</b> Weak linkages between DAWR and local industries in international trade protocol development and negotiation Lack of people understanding the entire system Different "languages" used in groups cause communication challenges Several growers have mistaken expectations about market access opportunities Higher level committees underestimate the on-ground complexity of SAs and AWM Local industries cannot readily access information about international trade rules	Interaction Interaction Interaction Actor Interaction Actor Interaction Interaction Infrastructure	Low system connectivity Low system connectivity Low system connectivity Lack of clear market access pathways Low system connectivity Lack of clear market access pathways Low system connectivity
<b>F4: Guidance of search</b> Developing a shared local vision can be challenging Clear guidance lacks on how to do systems approaches	Actor Interaction Institutional	Lack of clear market access pathways SAs are problematic Lack of clear market access pathways
<b>F5: Market formation</b> Most markets prefer 'one-kill-step' systems Lack of a state government-funded trapping grid without third-party pest monitoring system Third-party pest monitoring system will add considerable cost to industry Negotiating and changing protocols are lengthy and costly processes Time gap between last industry input and government trade protocol negotiations can lead to impractical protocols	Institutional Infrastructure Institutional Institutional Interaction Institutional	SAs are problematic Feasibility signals lacking Feasibility signals lacking Feasibility signals lacking Low system connectivity
<b>F6: Resource mobilisation</b> Investment from government and industry lacking	Infrastructure	Feasibility signals lacking
<b>F7: Creation of legitimacy</b> Higher level actors are perceived as underestimating on-ground challenges Trust in government support for market access varies between regions, lowest for Australian Government Local industries may underappreciate government and industry body efforts to facilitate trade	Actor Institutional Interaction Actor Interaction	Low system connectivity Low system connectivity Low system connectivity



The problems identified were investigated for interconnected elements or clusters, representing blocking mechanisms (adjusted from Turner et al., 2016) that hinder local industries from embracing AWM and systems approaches.

First, there is a *lack of clear change pathways* for local industries interested in pursuing AWM and systems approaches. Hence, the innovation system creates insufficient conditions for entrepreneurial activities to flourish (Hekkert et al., 2007; Kruger, 2017). Lacking capability is a common AIS weakness (Klerkx et al., 2012). Kruger (2017) identified low local capability to achieve AWM for QFly suppression. Many growers also have limited understanding of international trade rules; nationally agreed procedures for ALPPs are still being developed, and relevant international standards are regarded as vague. While state governments and peak industry bodies make considerable contributions, capacity is limited to assist local industries with identifying and pursuing new trade pathways. Information is not easily accessible, for example, several growers find trade-related information provided on the internet hard to interpret for their situation.

Second, *low system connectivity*, or weak network failure (Klerkx et al., 2012), means several local industries are weakly connected with the broader QFly management innovation system. This limits effective knowledge diffusion between local industries and the innovation system as well as amongst local industries, thereby preventing the holistic approach needed to progress innovation (Nederlof et al., 2011). This is evident from the different expectations across levels about the acceptance of ALPPs as part of systems approaches for international trade. Industry is seen as too removed from international trade negotiation process and this could cause impractical trade protocols. There is possible under-appreciation of the complexity of AWM and systems approaches at higher levels and an under-appreciation at the local level of the investments governments and industry bodies make to facilitate trade. Fragmentation between actor groups result in silo-ed knowledge and “languages”.

Third, a *lack of feasibility signals* challenges the demand for proposed solutions, that is, when it is not clear that they make economic sense and seem achievable (Busse et al., 2015). When AWM is used as part of a systems approach, it requires considerable logistical systems to be put in place (see F1 under 4. Results). Concerns exist that the cost to industry involved in potential third-party monitoring of trapping grids may make them uneconomical to use. For industry representatives to deal with various actors at different levels in industry and government, and to initiate joint decision-making between key actors, come at considerable transaction costs.

Fourth, *systems approaches are problematic*, including the difficulty to statistically prove their effectiveness<sup>1</sup>, low market acceptance and potential industry back-lash if Australia needs to accept systems approaches for imports. Factors other than scientific evidence accompanying a market access application can influence negotiations. Addressing this issue falls outside the scope of this article. The lack of feasibility signals and systems approaches being problematic hinder entrepreneurial activity, resource mobilisation and the legitimacy of AWM and systems approaches.

More broadly, this work shows that the modern-day biosecurity push for harmonisation and categorisation is challenged by regional differences. Local industries can be easily left behind in the biosecurity journey if they are not well-connected to the broader innovation system.

## 5.1. Recommendations for policy intervention

The recommendations provided here are not an exhaustive list, but rather they begin a process to alleviate some of the key pressures on local industries. Fig. 1 sketches the blocking mechanisms' impact on the innovation functions and where the proposed policy interventions can alleviate these issues. Other relevant recommendations are also made by Kruger (2017), in particular the need for knowledge brokering and

co-regulation to secure a sustainable funding stream for AWM.

### 5.1.1. Investigate and support interconnected innovation platforms

This can address the low system connectivity, improve co-production of knowledge and lead to clearer market access pathways for local industries. Innovation platforms refer to the deliberate creation of spaces where heterogeneous actors interact to undertake information-sharing, knowledge-development and implementation activities to solve a common problem. This enables co-evolving technical, social and institutional components in the innovation system (Kilelu et al., 2013).

Local QFly management groups represent innovation platforms where different knowledge systems meet, e.g. representatives from growers, packhouses, local government, crop consultants and state government (Kruger, 2016). Here they develop coordinated QFly initiatives suitable for the regional context in pursuit of strengthening trade. The grower survey suggests that growers' trust in their local management group tends to be high.

Policy intervention is therefore required to ensure local management groups are well-connected with higher level bodies and research groups involving multi-directional information to and from local industries. Given the different roles of the Australian and state/territory governments, it suggests that there is a need for inter-connected platforms across different levels, such as at the local, state or national levels (Nederlof et al., 2011). The design of such intervention is best negotiated amongst key actors, such as local management group representatives, research groups, industry bodies and market access government staff. This is to meet their needs and expectations, ensure maximum buy-in, and to enable a good fit with existing structures. Effective intermediation between groups is vital to ensure effective coordination, information brokerage and resolving tensions (Kilelu et al., 2013). Well performing innovation platforms are likely to increase actors' trust in the innovation system and strengthen the guidance in the search and legitimacy of AWM and systems approaches amongst local industries.

### 5.1.2. Offer training opportunities

Currently knowledge about market access is concentrated amongst a relatively few actors in government and industry bodies. This knowledge base can be broadened by offering training to people operating at the local level, such as management group members and crop consultants; and private consultants interested in assisting industries with pursuing trade to protocol countries. This will contribute to a bigger support network that can guide local industries on change pathways and can also strengthen the capability of local actors and others to participate in the co-production innovation process based on a more shared language (Busse et al., 2015). Training opportunities could involve a joint initiative between the Australian Government, state governments and national coordinating bodies to ensure international and domestic market access is covered. A module on softer skills, such as negotiation, facilitation and conflict resolution, could further equip individuals with guiding local industries to improved market access.

### 5.1.3. Minimise transaction cost to industry

This can strengthen the feasibility signals of QFly AWM and industry's ability to be more self-reliant by minimising the time and effort that industry representatives need to spend to gain cooperation and support from key actors. Examples include making it easier for industry to get the “right people” in one room or accessing past government QFly-trapping data. Other opportunities for improvement include further strengthening stakeholder coordination; minimising the effect of staff changes, fostering a client-oriented ethos and strengthen grower guidance, in particular by regularly updating nationally agreed fruit fly management principles and procedures to reflect advances in science.



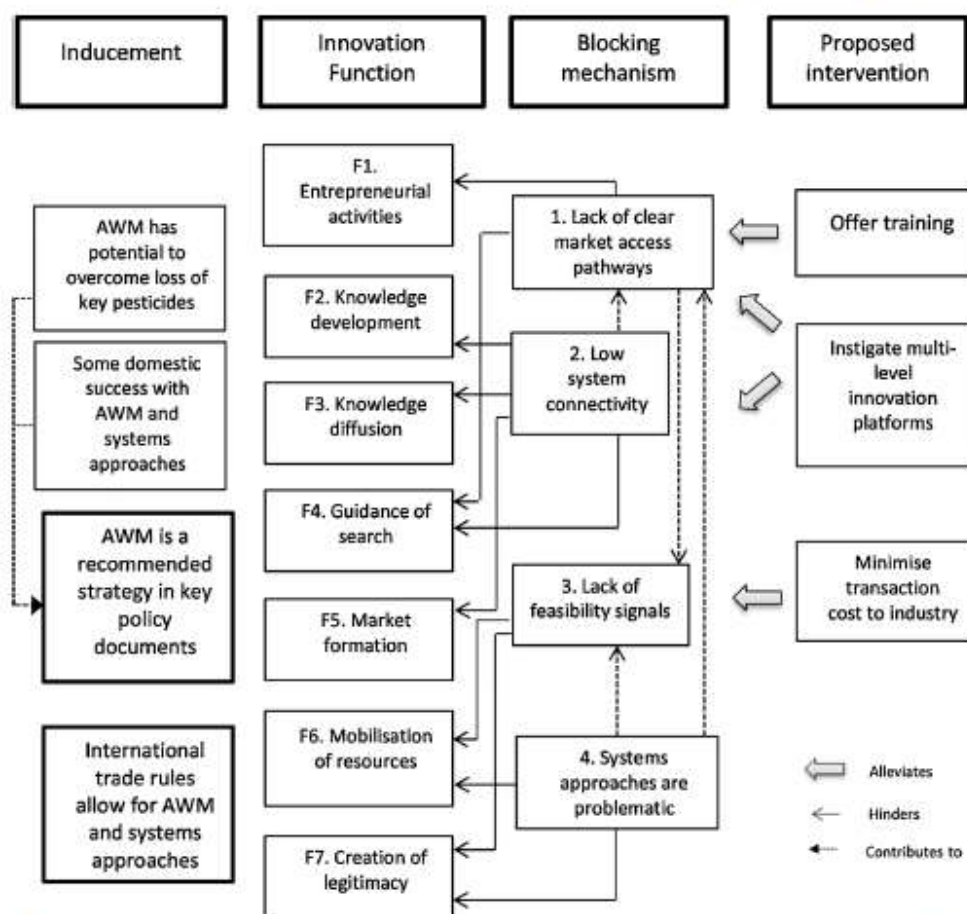


Fig. 1. Main blocking pathways to creating an enabling environment for industry-driven AWM and entry points for proposed interventions (adjusted from Bergek et al. (2008)).

## 6. Conclusion

This article explored how to create a more enabling environment for local horticulture industries to pursue AWM of QFly as part of a systems approach. It comprises a complex domain that is multi-levelled and multi-faceted, and where innovation co-production through effective negotiation processes is essential to develop trade-related systems that meet both the needs of growers and markets.

This work has demonstrated that a functional-structural analysis is a powerful tool to identify what else is required beyond technological advances to ensure investment in innovation translates into industry progress. Capacity-building and local industries well-connected with the broader innovation system stand the best chance to overcome the challenges of lacking clear change pathways, low system connectivity and lack of feasibility signals. The analysis illustrates that the transition towards shared responsibility requires a rethink of the innovation system to minimise transaction cost to industry, rather than the mere transfer of certain tasks from government to industry.

Prudent next research steps include stakeholder consultation to inform the design of innovation platforms and/or other ways to strengthen the interconnectedness of the QFly management innovation system, especially with the local level. This could be informed by a social network analysis that investigates how information currently

flows formally and informally throughout the system and to understand the position of actors in the system (Klerkx et al., 2012). Given the expectation that the private sector will deliver services traditionally provided by government, a deeper investigation is needed into the skills and support that private entities, such as consultants, need to effectively support local industries in their QFly-affected market access pursuits.

## Disclosure statement

I, Heleen Kruger, receive no financial interest or other benefit arising from the direct applications of this research. This research has been conducted in partial fulfilment of a PhD.

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# Chapter 5. Conclusion

## 5.1 Introduction

This work explored the social and institutional aspects of industry-driven fruit fly AWM that impact on the success of these ventures. QFly is a particularly problematic pest as it has a wide host range with most fruit and vegetables susceptible to varying degrees. The pest is also of considerable concern to many of Australia's horticulture trading partners. Many domestic and international markets place costly restrictions on produce from QFly-affected areas to reduce the risk of produce being a source of pest infestation in their jurisdictions.

The challenge has recently intensified as the two key chemicals traditionally used to manage the pest have been restricted. This coincides with reduced direct on-ground government support for dealing with the issue of QFly in many regions, with cuts in terms of pest management, pest monitoring activities and extension services. In these regions it is now up to local industries to achieve the needed collaboration between various stakeholder groups and risk contributors in order to instigate and maintain regional QFly management programs.

AWM is increasingly in the spotlight as a key alternative QFly management option (PHA, 2008; White et al., 2011; Fay et al., 2011). It promises a reduced need for pesticides and AWM is acknowledged in international trade rules as an acceptable measure to manage pests, such as fruit fly. Some successful cases of industry-driven AWM exist in Australia, most notably in Central Burnett (Lloyd et al., 2010). However, the literature about AWM focuses predominantly on the technical aspects of these undertakings, while there is acknowledgement that it is often the social and institutional aspects that contribute to program failure (Klassen, 2005; Hendrichs et al., 2007), such as a lack of public participation (Mumford, 2000).

This study applied a mixed-methods approach across two phases to understand how industry-driven AWM for QFly can be strengthened. The key research questions explored were:

1. What social and institutional factors influence the success of industry-driven AWM at the local level and how can success be maximised? (Phase 1)
2. What are the main constraints to an enabling environment for industry-driven AWM implementation and how can these be mitigated? (Phase 2)

## **5.2 A summary of the research's contribution to AWM literature**

Given the lack of literature about the social and institutional aspects of AWM, this research's key findings present a new critical way of thinking about industry-driven AWM and how to maximise the chances of success for such programs.

Broadly speaking, this work illustrates that achieving desired outcomes from dealing with QFly through industry-driven AWM is first and foremost a matter of learning to deal with the relational character of both the QFly problem and AWM programs. Each region is unique based on the social profile of the local people involved as well as the local ecology and climate that influence how QFly behaves in the region. Different stakeholders across levels are focusing on different aspects of the QFly problem; applying diverse logics; and therefore construing biosecurity differently. This reflects the point that Hinchliffe et al. (2013) made about biosecurity more broadly. Currently biosecurity is approached as an issue of segregation based on 'borderlines', that is, where 'clean' areas are distinguished and protected from 'unclean' areas. They argue that biosecurity rather involves a case of 'borderlands' in which various stakeholders, institutions, incentives, logics, practices, technologies and environmental conditions interact, including the intensity and characteristics of these interactions.

Figure 7 represents the convergence of the key findings of this work and will form the basis of the rest of the discussion in this sub-section. It represents key lessons from the application of rationales contained in the SES and AIS literatures together with the study's empirical evidence across Phases 1 and 2.

This research used as its conceptual basis the first tier of the SESs Framework (McGinnis and Ostrom, 2014) as outlined in Chapter 1 (Figure 1). Here, AWM is an action situation that is situated within the natural world, i.e. the resource system (QFly behaviour, biology and ecology) and resource units (QFly pressure). AWM also involves interactions between a governance system and a range of actors.

By building on Figure 1, Figure 7 shows that AWM programs comprise three key components (listed below) and are nested across levels. The two-way arrows in Figure 7 emphasise the importance of multi-directional information flows throughout this multi-level system and between the three components. This is to ensure that the different components and levels are responsive to each other in order to achieve a holistic approach that will make industry-driven AWM workable. The components are:

- *Social* – there are people and groups at the local, state, national and international levels whose actions, interactions and decisions (or lack thereof) can either facilitate or hinder AWM initiatives
- *Institutions* – there are formal and informal rules that apply at the local, state, national and international levels that influence the design and implementation of AWM programs
- *Technology* – the technologies and information that are available at the local level for QFly management flow predominantly from the broader fruit fly management innovation system that stretches across state, national and international levels.



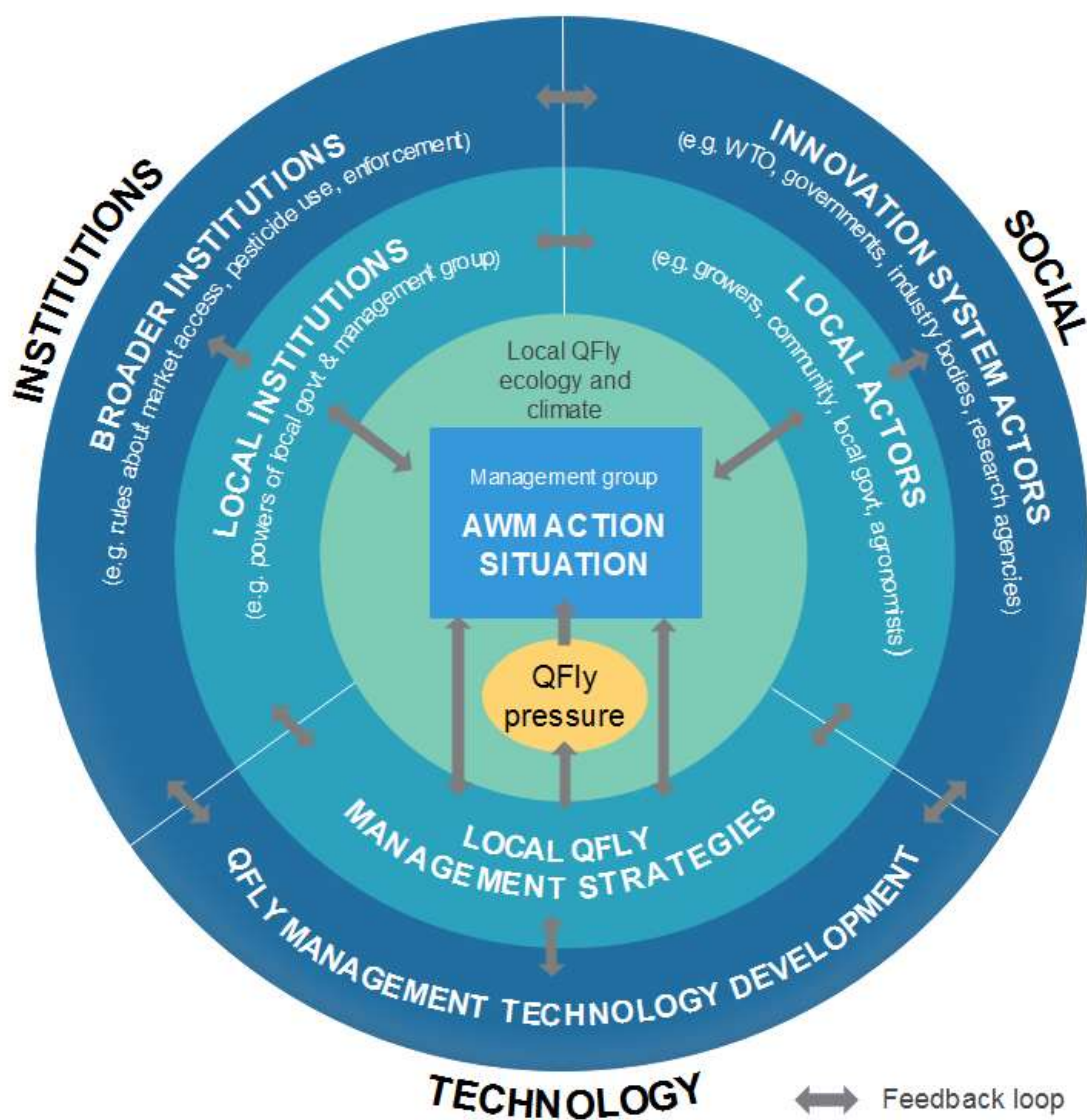


Figure 7. The ideal industry-driven AWM situation

An example of the importance of feedback loops between components includes the need to develop fruit fly management technologies (technology component) that will be accepted by national and international trading partners (institutional component). The need for feedback loops across levels within a component can be illustrated with the importance of state level institutions being designed to enable local institutions that will make industry-driven AWM workable at the local level (institutional component), such as ‘smart regulation’. This will also require feedback loops with and between stakeholders across local and state levels (social component).

This research focused primarily on the social and institutional aspects of AWM. A key argument of this research is that the social and institutional aspects of industry-driven AWM influence the transaction costs of achieving industry-driven AWM and therefore have a major bearing on the feasibility of such programs. These costs are easily overlooked in cost benefit analysis of AWM programs. On the one hand there is a need to invest in transaction costs, such as by establishing/strengthening linkages and maintaining communication across regional, state and national levels. On the other hand, much transaction cost can be saved when appropriate institutions are developed as a result of deliberations across levels and between components. For example, it is more likely that such linkages will result in trade protocols that are accepted by trading partners and that are practical and cost-effective at the local level. The transaction cost involved for growers to indefinitely keep risk contributors motivated to manage QFly (such as town residents and other landholders with QFly hosts on their land) based on voluntary approaches alone, can render AWM program unfeasible.

Within the context of Figure 7, there are five principles that are important to understand in order to effectively progress industry-driven AWM. It is with these principles, which sometimes overlap with each other, that the core findings of this research across the five articles are pulled together. These principles are discussed below and are as follows:

- Principle 1. The local social profile influences the prospects of successful AWM.
- Principle 2. AWM needs to be based on adaptive co-management.
- Principle 3. Local industries need help to help themselves.
- Principle 4. AWM programs need strong two-way connectivity with the broader QFly management innovation system.
- Principle 5. Industry-driven AWM programs need institutional adjustment.



### **5.2.1 Principle 1. The local social profile influences the prospects of successful AWM**

With the international and national drive for harmonised phytosanitary measures (IPPC 2006; NFIS Implementation Committee 2009) it can be easy to underestimate the impact that the uniqueness of different local regions has on their ability to achieve AWM. The AWM literature recognises that the geographical and ecological profile of a region influences the suitability of a region for AWM. As explained in Chapter 1, naturally occurring barriers (Flores et al., 2010; Sharov, 2004), such as mountains, deserts, or large lakes, or adjacent areas with unfavourable climates (Gonzalez and Troncoso, 2007), are recognised as helpful in establishing AWM. Likewise a limited extent of QFly hosts beyond commercial orchards is also known for easing the implementation of AWM. However, it is seldom recognised that the social profile of local actors (Figure 1), such as the growers and adjacent town communities, also influence the prospects of a successful AWM program. Regions with unfavourable social profiles will probably require greater resources to achieve and maintain AWM than regions with favourable profiles.

The application of Ostrom's eight design principles for robust common-pool resource institutions (Cox et al., 2010; Marshall, 2008; Poteete et al., 2010) to the case study findings highlight how certain social variables enable or hinder AWM (see Article 1). In particular, the local social profile will determine how hard or easy it will be to develop a set of local institutions for the AWM program that are widely seen as fair and supported by risk contributors. In other words, the local social profile impacts on the transaction costs needed to achieve and maintain AWM. Four such key social variables have been identified from the case study findings. These social variables are briefly discussed below.

First, areas with high heterogeneity of QFly risk contributors are likely to find it more difficult to set clearly defined boundaries (Ostrom's first principle) than will more homogenous grower communities. This includes identifying who needs to implement QFly

management activities, what is required from them and how to win their commitment.

Heterogeneous groups of growers generally have different on-farm objectives and different market requirements for the level of proof needed for QFly management. This makes it harder and therefore more costly to identify a common objective for AWM. For example, in the Riverina, a relatively small proportion of citrus growers are interested in exporting to premium QFly-sensitive overseas markets. A large proportion of the citrus growers are part-time growers supplying to the domestic juice market while earning other sources of income. As they are not fully dependent on their horticulture operations to sustain their livelihoods, it likely lessens their incentive to participate in AWM, whereas exporters would like to see QFly management implemented to the highest level in the region.

Heterogeneity also makes it more demanding to achieve congruence between appropriation and provision rules (Ostrom's second principle). When participants' investments are not proportionate to the distribution of eventual benefits, local people might view rules as unfair, which would discourage them from fully cooperating. This challenges decision-making (Valentinov, 2007) and adds to the transaction costs of achieving consensus (Ostrom, 2010; Chaddad and Iliopoulos, 2013). Identifying who is gaining most from biosecurity measures, and therefore who ought to contribute most, is not always evident (Donaldson, 2013). For example, it cannot be taken for granted that international markets will accept AWM as part of a systems approach and render post-harvest treatments, such as cold sterilisation, obsolete. This situation is less challenging if there is greater homogeneity amongst growers. Moreover, heterogeneity can challenge collective choice arrangements (Ostrom's third principle), as it requires the management group to have strong communication channels and trust relationships with more groups. This can challenge the management group's legitimacy and credibility across the region.

Second, the presence of high levels of social capital between all key participants may ease the establishment of AWM. This includes established trust and communication networks,

champions and leadership. In Central Burnett, relationships between growers, crop consultants and the state government department research team have been fostered over many years by previous collaborations. The crop consultants were strong champions for AWM, both amongst growers and the town community. The research team was also in close contact with their colleagues who are responsible for negotiating domestic trade protocols, which eventually resulted in ICA-28. The fact that most growers employ one of the local crop consultants with whom they communicate on a regular basis, means that growers have the ear of key decision-makers, as all crop consultants are management group members. Established trust and communication networks therefore assist in achieving collective choice arrangements (Ostrom's principle 3). In addition, strong social capital could signal a high level of social norms that translate into informal institutions (Marshall, 2005) contributing to 'enforcement' through informal contracts (Putnam, 2001). This facilitates the achievement of Ostrom's principles 4 and 5 that refer to the need for monitoring of compliance and graduated sanctions in case of violation. However, it is important that social capital is not located in just some participating groups, as some associations could hinder progress and sustainability by maintaining cliques and/or it could protect those who seek their own self-interest (Pretty, 2003).

Third, the presence of existing social mechanisms that provide opportunities for monitoring on-farm QFly management activities is likely to facilitate collective action and lower transaction costs. For example, in Central Burnett a high proportion of growers employ crop consultants or scouts for pest management. This enables low-cost monitoring during field visits of whether growers are effectively managing the pest. In the Riverina, packhouses also offer the opportunity to implement relatively low-cost monitoring systems, if they are willing to insist on their grower suppliers providing proof of QFly control. However, this could be thwarted in times when there is a shortage of produce and supply chains ease their grower requirements in order to secure supply.

Fourth, the ratio between the number of growers keen to pursue AWM and risk contributors who have little incentive to manage the pest affects the cost and effort needed to establish AWM. In Central Burnett small town sizes make it possible for growers to fund town treatments. In areas with large rural towns, such as Griffith in the Riverina, this is less feasible. This renders those in favour of AWM dependent on awareness-raising activities to encourage town residents and others to manage the pest themselves.

### *Policy implications*

In the biosecurity and trade arena there is a push for harmonisation and standardisation. The varying profiles of the case studies illustrate that it is unlikely an ‘one-size-fits-all’ set of local institutions will be ideal for all AWM programs. The rules relating to how the AWM program is run, what the program involves and what it sets out to achieve are best negotiated locally with their design tailored to local circumstances. The AWM action situation (Figure 7) therefore needs to represent Enticott’s (2008) ‘spaces of negotiation’. This means there is a need for deliberation, negotiation and conflict resolution (Klerkx et al., 2010)—or what Mau et al. (2007) called ‘frank discussions’ in relation to the successful Hawaii AWM program—in order to find ways forward that enjoy support and commitment from a wide range of stakeholders.

### **5.2.2 Principle 2. AWM needs to be based on adaptive co-management**

Looking at the formal international and national requirements for fruit fly management, AWM and systems approaches (such as contained in the ISPMs and the QFly management Code of Practice), one could believe that AWM constitutes more or less standardised ‘spaces of prescription’ (Enticott, 2008), where successful AWM would predominantly rely on the introduction of materialities by applying QFly control technologies. Moreover, an entrenched view of agriculture innovation perceives growers as situated at the end of a technology development line. In this model technologies are typically invented and developed by scientists. These inventions are then in need of being transferred to growers

for their adoption. Many studies have shown that outcomes under this model can be disappointing, as limited uptake by farmers and other agriculture stakeholders is not uncommon (Leeuwis and Aarts, 2011). This technocratic view of development tends to be based on reductionist thinking. That is, reasoning that is predominantly based on objective and absolute knowledge is regarded as universal truth. However, local situations often involve high levels of complexity and uncertainty, due to a range of local and higher level factors that relate to both the issue at hand as well as broader contextual factors. Enticott and Franklin (2009) therefore point out that ‘expert’ knowledge should not be privileged at the expense of local knowledge and learning processes rooted in local socio-economic, cultural and political contexts. There is a need for a more constructivist and inclusive approach that is based on integrating different knowledge systems (Boxelaar et al., 2006) to develop control strategies appropriate for the local context.

Aspects of AWM that add to complexity and uncertainty include its collaborative nature, various on-farm objectives and that not all risk contributors may have incentives to continually manage QFly. As discussed in Chapter 4 (Article 1) and principle 1 above, a range of issues can impact on the ease of finding suitable local institutions that will enjoy wide support. In addition, the design of the AWM program requires a good understanding of the regional QFly situation, including QFly behaviour in and amongst crops and other local hosts and this might vary across years with different weather conditions (Clarke et al., 2011). Figure 7 illustrates that there is a need for an AWM management group to continually monitor QFly pressure and adjust local QFly management strategies accordingly.

Another key source of uncertainty revolves around market access. Central Burnett demonstrates that the anticipated market access based on certain conditions, such as access to certain protocol countries without the need for post-harvest treatments, does not

necessarily eventuate despite a successful AWM program. ALPP as part of systems approaches are not well accepted yet in the international trade arena.

Complexity and uncertainty can be best surmounted through adaptive co-management; that is, a flexible process of 'learning by doing' and by drawing on different knowledge systems (Olsson et al., 2004; Charles, 2007). This enables the design of an AWM program to be tailored to local conditions. These different knowledge systems include local ecological conditions and the distribution of QFly hosts; QFly biology and behaviour; market access requirements; applicable policies, regulations and other rules; risk contributors' motivations and attitudes; and community engagement.

The case studies illustrate that typically this co-production of knowledge based on different knowledge systems occurs within the local management group. Participating stakeholders can come from the local level offering different forms of local knowledge. Stakeholders from higher levels can offer knowledge on issues such as trade and QFly biology and behaviour. However, it can be challenging to have all knowledge systems represented and actively involved over time.

Local management groups therefore represent innovation platforms. Here participants engage in social learning, learning from each other and the activities implemented, to continually refine QFly-related management activities. From an adaptive co-management perspective, outcomes are closely monitored when changes are introduced to the AWM program to ensure that the system does not lose functionality. The knowledge that stakeholders build over time strengthens their adaptive capacity, as they learn what works and what does not in particular circumstances. Social learning requires solid communication processes that are well-facilitated, both horizontally between local players and vertically across levels. Evidence of adaptive co-management can be seen throughout the lead up to and the current management of the AWM in the Central Burnett region (see Box 2).

## **Box 2. Central Burnett – An example of adaptive co-management for fruit fly AWM**

The successful Central Burnett AWM program represents many aspects of adaptive co-management. Local crop consultants, researchers from the then QDPI and citrus growers closely worked together on various regional projects from the 1990s, resulting in trust-based amicable relationships between them. Jointly they decided on research priorities and QFly-related activities for the region, and discussed findings, which subsequently shaped in-field activities. Research occurred in the region, including in growers' orchards. Growers participated in some of the research activities, such as when male annihilation technique (MAT) was introduced on their properties. When AWM was launched in 2003, the local government was already involved to assist with community engagement about QFly to minimise pest pressure from towns. Other local horticulture industries in the region were also engaged in the AWM effort. Over the years, the QDPI research team regularly consulted with the state and federal market access staff, respectively. To this day if changes are introduced, such as less intense town treatments, the results are closely monitored to allow for rapid response in case of unfavourable results.

Adaptive co-management does not offer a 'quick fix', and the investment (transaction cost) to engage with different players and learning processes can be considerable, especially early on. However, it offers several important benefits over time:

- local knowledge of QFly issues in the local context increases
- management activities are suited to the local context and continually improve
- as a result of the above, local adaptive capacity strengthens, as learning occurs about what works and does not in the local context and under which circumstances
- a common narrative develops between key stakeholders, which is fundamental to developing the much-needed shared vision for AWM



- a more sustainable, fit-for-context and locally-owned initiative is eventually established.

### *Policy implications*

At the local level, the implementation of adaptive co-management requires a mind-shift from a key focus on implementing QFly management measures only—such as when the fenthion and dimethoate was still available—towards implementing measures with the intention to continually learn and adjust. This is captured in Figure 7 by the two-way arrows (feedback loops) between the AWM action situation, the local QFly management strategies and QFly pressure.

Integrating information from different knowledge systems means growers interested in instigating AWM need to actively build networks with others, including other growers (or representatives of different grower groups), experts in QFly behaviour and market access and community representatives, such as local government. Several of these may involve actors in the broader AIS (Figure 7).

A key contributing factor to well-functioning management groups is appointing members whose selection is based on positive personality traits, such as an aptitude for consensus-building, two-way communication skills, flexibility and the ability to sustain trust (Mau et al., 2007).

AWM programs need to achieve a balance between ‘top-down’ elements and ‘bottom-up’ components. Several aspects of market access represent ‘top-down’ elements where growers have little control, such as in the politics of market access negotiations as well as some prescriptions in trade protocols and the QFly management Code of Practice. It is therefore important that AWM programs first and foremost focus on achieving QFly suppression and see any market access requirements that have not been met yet as ‘bolt-on’ components.

For government and industry bodies, policy implications include making available the necessary experts to engage regularly with local management groups. The benefits of social learning can be maximised if staff turnover is minimised. Other ways in which local industries can be supported in achieving and maintaining AWM are discussed below.

### **5.2.3 Principle 3. Local industries need help to help themselves**

A considerable range of knowledge and capabilities is needed to achieve and maintain AWM. An ‘ideal type’ of this knowledge and capabilities was developed based on the Phase 1 case study research and in consultation with six AWM experts from national and state governments and regional QFly management groups. It was further refined after the input received during the Phase 2 interviews. The ‘ideal type’ of the knowledge and capabilities needed for AWM is summarised here for space considerations, while the full list is contained in Appendix 2:

- AWM program administration and management - Effective program cycle implementation, including planning, implementation and monitoring; securing funding, sound financial management, understanding broader institutional requirements, organising and facilitating meetings, and record-keeping.
- Conducting stakeholder interaction – including achieving a shared local vision, maximising uptake across all risk contributors, networking, advocating the program to key stakeholders, conflict management and supporting growers in their implementation of recommended practices.
- Understanding QFly behaviour and on-ground control – including knowledge of general QFly biology; QFly behaviour within the target region all year round; current on-ground control options and consistently implementing QFly control strategies across the district.
- Understanding market access requirements, including:
  - phytosanitary measure options – including the benefits and limitations of each

- formal market access standards – the relevant ISPMs, QFly management Code of Practice and existing trade protocols; and related concepts such as probit 9 levels, appropriate level of protection and risk management
- informal aspects and requirements – including market expectations of the target country and the political aspects of trade negotiations
- the market access application and approval process, including gathering rigorous data and the inclusion of suitable verification steps in the protocol
- consistent implementation of market access requirements, including rigorous monitoring and documentation maintenance and implementing corrective actions when needed.

In Phase 1 interviewees pointed out that it can be difficult to establish the needed networks to access the knowledge and capabilities that they need to achieve AWM. A key theme was that many growers felt unsupported in their QFly management and market access endeavours. This is how a Riverina grower expressed it:

*‘I’d rather see the government be the support worker...because the policeman situation is just making things a lot more difficult...Government has pulled out all the support staff, but they kept the regulatory staff.’*

The case studies also demonstrated that knowledge and capabilities differ significantly between regions. In Phase 2 some interviewees pointed out that stakeholders at higher levels easily assume that growers have certain levels of knowledge or capabilities (such as how to achieve collective action), but in reality this varies considerably. Knowledge and capabilities at the local level depend on a wide range of factors, such as how long the region had to deal with QFly (in some regions QFly only recently became an issue); the availability of trusted local experts such as crop consultants well versed in QFly

management; the grower group's access to the relevant networks and previous experience in working together.

In addition, interviewees across Phases 1 and 2 also spoke about a range of issues that added to the cost and effort to achieve AWM and that could potentially be made easier. For example, these included the difficulties with tapping into relevant networks that deal with QFly management and QFly-affected market access. Several interviewees spoke about the negative impacts of the high level of staff turnover and restructuring in government departments. It means that growers struggle to maintain relationships with government staff that are built on a mutual understanding of their local QFly situation, a shared vision and possible ways forward. Interviewees also spoke about the difficulty of obtaining past trapping data from state governments in some areas that could assist with future planning of QFly management. Moving forward sometimes depends on joint decision-making between key stakeholders from different organisations and it can be difficult for industry to '*get them in one room*' to discuss the issue and agree on a resolution.

### *Policy implications*

Given the considerable numerical decline in public extension officers (Hunt et al., 2014) training could be offered to those who are likely to fill this gap, such as private crop consultants, key growers and other interested local people. This can assist in strengthening local knowledge and capacity on issues such as trade; QFly biology, behaviour and management; and community engagement. However, training without strengthened intermediation between local level actors and the rest of the QFly management innovation system will do little to move beyond technology-transfer approaches. Apart from mere local capacity building, training can also be seen as a tool that will support innovation platforms and other collaborations by more quickly facilitating in-depth conversations between growers and other stakeholders. This will strengthen the feedback loops that need

to exist between local groups and the actors in the broader AIS (see Principle 4 below and Figure 7).

Another way to support local industries is to minimise the transaction costs to local industries to achieve and maintain AWM. Industry-driven approaches will benefit from policies and procedures that are developed to minimise cost and effort to industry. Based on the interviewees' feedback, opportunities for improvement include further strengthening stakeholder coordination, minimising staff changes (or the effect thereof) and fostering a client-oriented ethos in government departments. This work also argues for more innovative policy-making, in particular for more power at the local level to put in place enforceable systems to achieve and maintain collective action and sustainable income streams (see Principle 5).

#### **5.2.4 Principle 4. AWM programs need strong two-way connectivity with the broader QFly management innovation system**

Following on from principle 2, AWM can easily be seen as the mere implementation of a certain set of pest management measures by a critical mass of risk contributors within any geographical area. To a great extent, a focus on the mere implementation of QFly management activities by individual growers was the norm for QFly management in the past, when growers could rely on the application of the now restricted fenthion and dimethoate. Within this logic it can be easily assumed that the main form of support that local industries need is the production of effective pest management measures that need to be transferred to local industries for their adoption and implementation.

Innovation studies show that successful innovation that results in positive on-ground change tends to result from a co-evolutionary process involving concurrent technological, social, organisational, and institutional change. Here growers are best conceptualised not as mere adopters, but as partners and entrepreneurs in the innovation system (Klerkx et al., 2012b). Complementary to adaptive co-management thinking, successful innovation

involves changed narratives and discourses that come about between the interacting diverse stakeholders that are part of the innovation system (Leeuwis and Aarts, 2011). This includes the notion that a well-functioning innovation system will create conditions that make entrepreneurial activities flourish (Hekkert et al., 2007; Negro et al., 2007). In other words, a well-functioning fruit fly management AIS that promotes AWM will deliver the needed institutional, social, and technological change that will maximise the chances for industry-driven AWM to flourish. This is dependent on strong feedback loops between local AWM programs and the broader QFly management innovation system (Figure 7).

Across both phases of the research there was evidence that local industries easily become disconnected from the broader QFly management innovation system. For example, in Phase 1 interviewees spoke about the difficulty of establishing the needed networks and finding information and guidance to instigate AWM.

In Phase 2 interviewees spoke about the fact that research findings are often inaccessible to growers, both in terms of physical access as well as the way in which they are presented (e.g. many growers will not read scientific journal articles). On-going work, such as the 'Fruit fly body of knowledge', is attempting to address this issue. The disconnect is intensified by the loss of public extension services, where extension officers were key intermediaries between the on-ground level and higher policy, research and market access groups.

In addition, across both phases various interviewee feedback suggest that the grower voice is not well represented in national dialogues about QFly management. Higher level governance bodies may underestimate local complexities and overestimate the knowledge and abilities that local stakeholders have. While peak industry bodies make a considerable contribution to filling this gap, not all growers in a particular industry might see their peak industry body as representing their concerns. This was particularly evident in the Riverina citrus industry, where support for Citrus Australia is far less than in Central Burnett. Peak

industry bodies also have limited resources that prevent them from being intimately involved in all AWM programs (or attempts thereof) to develop an in-depth understanding of local issues.

### *Policy implications*

A key way forward that is based on both literature and feedback from interviewees is the need to support knowledge brokering and intermediation to establish feedback loops between local and higher levels of the QFly management innovation system (Figure 7). In order to ensure local industries are well-integrated partners in the innovation system to co-produce new, integrated knowledge with other innovation system stakeholders, there is a need to fulfil key boundary-spanning functions (Klerkx et al., 2012a; Klerkx and Leeuwis, 2009), including the components listed below. These functions are easily overlooked as they are often invisible and hard to measure (Meyer, 2010; Klerkx and Leeuwis, 2009).

- *On-ground demand articulation* – including assisting local industries with finding a shared vision to identify and articulate their technology, knowledge, funding, and policy needs (Klerkx and Leeuwis, 2009) to achieve AWM.
- *Information translation* – to connect ‘external’ information with the local context and growers’ existing knowledge (Klerkx and Proctor, 2013) in language that growers find useful (Klerkx et al., 2012a). This requires appreciation of the formal and informal knowledge that growers already have (Turnhout et al., 2013; Fazey et al., 2013; Oreszczyn et al., 2010). Likewise, local issues and opportunities are ‘translated’ to other players in the innovation system in order to contribute to the co-production of knowledge.
- *Network establishment* – including local horizontal networks and vertical networks with higher levels of policy-making (Kilpatrick and Falk, 2001) and researchers (Klerkx et al., 2012a; Meyer, 2010) thereby strengthening supply and demand signals for knowledge, capabilities and resources (Turnhout et al., 2013). ‘Upward’



information flow assists policy-makers and researchers to be responsive to local industries' needs (Klerkx and Leeuwis, 2008). Local horizontal networks include the need for capacity building to create new organisational forms (Kilelu et al., 2013).

- *Innovation process management* – working towards better arrangements in the multi-actor network, including facilitating cooperation and learning (Klerkx and Leeuwis, 2009).

In addition, instigating and supporting horizontally interconnected innovation platforms can strengthen connectivity between on-ground AWM activities and higher levels of decision-making. As in the case of adaptive co-management (Principle 2), this involves creating collaborations between heterogeneous stakeholders to undertake information-sharing, learning from each other and in the process developing new integrated knowledge. Innovation platforms can be situated across different levels, such as at the local, state or national levels, for example, by connecting local AWM management groups with multi-stakeholder groups at state and federal level. This will aid local industries to better meet their information and other needs. Upwards information flow can strengthen the grower voice to create a better understanding about the complexities of AWM at the local level and thereby contribute to improved decision-making at higher levels about how to best support local industries. The presence of QFly coordinators at regional, state and national levels can make an important contribution to forging these connections.

#### **5.2.5 Principle 5. Industry-driven AWM programs need institutional adjustment**

In the modern Australian biosecurity paradigm state and federal governments tend to favour market-driven approaches, including deregulation and a push for greater industry and community self-reliance. Yet, local industries remain embedded in various levels of institutions at local, state, national and international levels that set the conditions for what can be done and not done at the local level (Figure 7).

In particular, at federal and state levels biosecurity is seen as a shared responsibility between government, industry and the broader community. Here growers and community members can easily be seen as ‘active agents’ with a shared responsibility and who need to be mobilised to contribute to achieving certain outcomes (Curtis et al., 2014; Gill, 2011). Such mobilisation is then often enacted through awareness-raising and education (Curtis et al., 2014).

Ostrom’s principles 7 and 8 for robust local institutions provides insight into how local industries can be best embedded in higher levels of institutions (see Article 1). Ostrom’s principle 7 ‘Minimal recognition of rights to organise’ refers to the importance of local industries developing their own rules that are recognised and supported by external authorities at local, state and higher levels. This contributes to the legitimacy and enforceability of these rules. Principle 8 ‘Nested enterprises’ is concerned with resources that are part of larger multi-level systems. It has been found that neither a reliance on the local level, nor broader level institutions alone are successful in addressing resource maintenance issues. Here institutions are best developed in a nested approach, where different layers complement each other. Local industries adjust rules to local circumstances, whereas larger-scale institutions regulate the interdependencies between smaller units and they may intercede if issues that threaten sustainable resource maintenance fall outside the control of local resource users (Ostrom, 2005).

A major challenge for industry-driven AWM is dealing with QFly pressure from land beyond commercial orchards, as host plants in town backyards, and on peri-urban and public land, can present significant QFly breeding spots (Marte, 2007; Lloyd, 2007; Dominiak et al., 2006). Public support is a key requirement for the success of AWM programs (Hendrichs et al., 2007) and a lack thereof is a greater contributor to AWM program failure than poor technology (Dyck et al., 2005).

A key theme across the case studies was the absence of any way for local communities to

go beyond reliance on voluntary approaches to address QFly pressure from towns and other private land. Currently legislative power rests predominantly with state governments, but they are reluctant to introduce enforceable measures that favour industry, as is evident from the policy documents such as *Management of fruit flies in New South Wales – Policy* (issued 22 August 2014) (NSW Trade and Investment, 2014). This institutional challenge means that the only way many local industries can deal with the QFly pressure coming from towns and other private land is through awareness-raising and education.

However, the case studies confirm the finding of Curtis et al. (2014) that a lack of awareness is not the only barrier to behaviour change. The case studies show other barriers to QFly management for several landholders. This includes that it might not make economic sense to manage QFly as recommended QFly management practices can be expensive and/or time intensive. Other challenges include absentee landholders, derelict orchards and community apathy. At least 89 per cent of growers surveyed in all case studies agreed that QFly breeding in towns increases on-farm QFly pressure. However, only a maximum of 42 per cent of case study respondents (in the case of Leeton-Carrathool in the Riverina) believed that regular education activities would ensure that town residents would adequately manage QFly on their properties. This suggests a limited potential that growers will voluntarily contribute to a reliance on awareness-raising activities to stem QFly pressure from towns.

In addition, another major concern for industry-driven AWM is how these programs will be funded over the longer term. In many regions establishing an income stream from growers—as the main beneficiaries and/or local risk contributors—is dependent on instigating voluntary contributions. However, the Central Burnett case study demonstrates that relying on grower voluntary contributions to implement town treatments is thwarted by free-riding when some growers refuse to contribute while still benefiting from reduced QFly pressure from towns. This causes other contributing growers to also ‘opt out’. For

example, fifty-nine per cent of growers who responded to the Central Burnett survey said that they would contribute to town treatments only if others contributed too.

Ostrom (2005) is the leading scholar who advocates self-organised resource governance institutions in order to ensure local institutions are tailored to local circumstances.

However, she does not exclude complementary state intervention to back-up industry-driven collective action in light of the needed nested approach between levels. She argues that it can give local people the needed trust that others will cooperate and that their individual efforts will not be jeopardised (Ostrom, 2005).

### *Policy implications*

This work advocates ‘smart regulation’; that is, using complementary policy instruments and behavioural interventions to assist in overcoming the weaknesses of individual instruments, while still capitalising on their strengths. For example, by combining approaches that draw on people’s intrinsic motivation to ‘do the right thing’ with legal instruments that can be enforced. The introduction of various regulations and policy adjustments can ensure that ‘market rule’ and industry ownership are reinforced, while they address issues that fall outside the reach of market forces. ‘Smart regulation’ can be an important tool in modern biosecurity partnerships and shared responsibility contexts where government encourages industry self-reliance, but where industry has limited control over certain groups to contribute to managing biosecurity risks. This reflects Ostrom’s Principle 8 ‘Nested enterprises’ for robust local institutions as is illustrated in Figure 7.

Several policy instruments to deal with QFly pressure from non-commercial horticulture land were explored based on the case studies, the Landcare program and overseas AWM experience. They could potentially be used in combination with each other or with other policy instruments to ensure the overall approach is fit for the local context:

- Community education and awareness-raising – if well implemented, this approach can be effective in reaching people who have an intrinsic motivation to manage the

pest, such as households that value their backyard produce. The cost and effort needed to sustain effective awareness campaigns are easily under-estimated.

However, such campaigns will do little to overcome barriers to behaviour change that are not related to a lack of awareness (Curtis et al., 2014).

- Broad-scale state regulation that enforces QFly management on all properties – the benefit of that approach is that it applies consistently to all risk contributors.

However, it is very costly to monitor and enforce. There are also moral challenges, such as when landholders are physically or financially unable to manage QFly.

Magistrates courts easily misunderstand the level of QFly control required and have rejected prosecuted cases.

- Devolved power by endowing certain local groups with powers that currently rest with state government – including the ability to enter private property and/or prosecute landowners who fail to manage horticultural pests. This lessens the burden on state governments to carry out monitoring and enforcement. It is applied in some parts of the US, such as Oregon and Washington, under the 2011 Washington Code (Title 15 Agriculture and Marketing, 15.09 Horticultural Pest and Disease Board). However, in the Australian context authorities may view this as favouring industry needs over those of other community groups and may be reluctant to implement such an approach.
- Devolved power to the local level to enable industry, in partnership with local communities, to devise rules appropriate for the local context – including where appropriate allowing the use of enforcement as a ‘back-up’ mechanism. This would align most closely with the underlying principles contained in much of the community engagement literature that values community involvement in the decision-making processes of issues that affect them. However, there have been mixed results in other areas of NRM when more local self-determining powers

were allowed (Berkes, 2010). Potential adversarial effects if not implemented with care include conflict, ‘power grabs’ by some groups (ibid.) and dealing with uninformed people who try to influence the program (Dyck et al., 2005). Generally speaking, such approaches require considerable investment and skill to be successful.

- Legislated cost recovery-structures – A legislated income-stream can facilitate industry and other appropriate local stakeholders to implement on-going and consistent pest treatments in QFly risk areas in combination with community awareness activities. Such an income stream can come from mandatory contribution from growers, the state and possibly town residents and is used in the SIR program for Codling Moth control in Canada’s British Columbia province (Anon., 2011). It could, however, encounter resistance from growers and others who are expected to contribute.

### **5.3 Other implications for social theory**

This study has identified several implications for theory on different fronts and they are summarised here. This thesis contributes to scholarly literature about SESs, in particular the commons, adaptive co-management and community engagement for NRM; as well as about the social and institutional aspects of biosecurity in general. As this section deals with biosecurity and natural resource management in agriculture more broadly, the term farmers will be used rather than growers, except when specifically referring to the QFly context.

Broadly speaking, this work contributes to a wider scope in rural sociology literature by focusing on the competitive, trade-related aspects of horticulture. Mainstream contemporary rural sociology tends to predominantly focus on the sustainability aspects of agriculture (Enticott, 2009).

### **5.3.1 Contributions to the SES literature**

The literature review revealed that there is a lack of scholarly work focusing on the influence of market requirements on SESs, including their influence on adaptive co-management. This work contributes to filling this gap. For adaptive co-management theory, lessons from industry-driven AWM show that the influence of the market presents top-down elements that can cause tension with the need for locally adapted programs. It illustrates that a sensible approach is to first and foremost focus on how to best manage the resource (here maintaining low or no QFly prevalence) in the local context. While it is important to consider market access requirements early on when the AWM program is being designed, they are best seen as bolt-on components to a locally tailored program.

Moreover, a large power differential exists between the state and farmers owing to the international and national biosecurity-related institutions that also contribute to top-down elements to pest management. This challenges the need for shared authority between stakeholders to achieve a certain goal. Shared authority is generally a key component of successful adaptive co-management (Plummer and Armitage, 2007). For example, local industries are greatly dependent on government negotiations with prospective importing partners to achieve market access. If anticipated market access fails, local support for at least some aspects of an AWM program is likely to decline.

In the context of the commons, this work illustrates that the influence of market requirements can create diverse on-farm objectives related to different markets. Such heterogeneity is likely to increase the transaction costs of achieving a shared vision and therefore a widely-supported resource management plan. This is due to the need for more deliberation and negotiation amongst different farmer groups.

Relevant to theory related to both the commons and community engagement, this work demonstrates that if not all risk contributors are resource users voluntary cooperation is



likely to be challenged. In the QFly context this refers to landholders with QFly hosts on their land but who have little intrinsic motivation to manage QFly. This work illustrates how reliance on single policy measures is challenging, such as either voluntary approaches or broad-based state legislation enforcing landholders to manage QFly. Instead, it outlines how ‘smart regulation’ might be a prudent way forward. This is due to its ability to give legitimacy to the AWM program, to overcome the flaws of individual policy instruments and its flexibility to tailor approaches to local conditions. In particular, in the context of partnerships and shared responsibility complementary policy instruments can assist local industries to be more self-reliant. Complementary policy instruments can be locally tailored and address the key challenges such as apathy and free-riding. This can give people prepared to implement the recommended practice the assurance that their own attempts are not undermined by a lack of cooperation elsewhere, thereby sustaining trust in the program (Ostrom, 1990).

### **5.3.2 Contributions to the social sciences biosecurity literature**

Theoretical contributions to the social sciences biosecurity literature include lessons learned from applying Ostrom’s design principles for robust common-pool resource institutions to cooperative pest management. These lessons are significant in light of the push for industry-driven collective action to address pest issues as they bring to the fore several factors that farmers have little control over. This work illustrates that setting clearly defined geographical boundaries (Ostrom’s principle 1) is challenged by mobile pests as well as that pests like QFly can be brought in by travellers carrying infested produce. These factors render the geographical boundaries porous and there is little farmers can do about it without institutional and other forms of support.

Achieving on-going congruence between appropriation and provision rules and local conditions (Ostrom’s principle 2) is challenged in many regions by varying seasonal conditions that determine pest pressure. Some regions may experience years of no or low

pest pressure due to climatic conditions, such as cold winters or hot, dry summers for QFly. During these periods it may be hard to maintain the interest and investment of key local players such as local governments. When favourable conditions for the pest follow, such as a mild winter and/or warm, humid summer for QFly, engagement with these key players need to be re-established and might require significant transaction cost and precious time when quick action is crucial. Likewise, when crops are not affected by a pest after long periods of successful AWM, farmers may start to question whether the continued investment in managing the pest is warranted, as is the case with some in Central Burnett. Social memory by those who have witnessed crops being devastated by the pest then becomes vital to convince fellow farmers to keep up the investment.

Regional community-based NRM governance literature stresses the need for nested enterprises where tasks are assigned across levels based on the ‘principle of subsidiarity’, that is, the lowest level where the issues can be effectively addressed. In the context of Australia’s biosecurity governance and shared responsibility approach, the findings show that certain responsibilities, such as dealing with pest pressure from beyond affected commercial operations, are assigned at a level too low to enable effective solutions. This includes winning the support from people who have little incentive to manage the pest on their properties and dealing with porous boundaries that can allow mobile pests to enter a region. Currently power to deal with these issues are located at state government level. Hence there is a need for either state government interference, such as ‘smart regulation’ that could involve devolved power to the local level to empower either local government or local farmer groups with certain powers.

There has been limited application of AIS thinking in the crop protection literature (Schut et al., 2014). The research presented here contributes to filling this void for both in-field pest suppression and where pests are of phytosanitary concern to trade. This work also demonstrates the invaluable worth of systems thinking in supporting the governance of

complex biosecurity problems as solving one aspect of the overall problem may deliver limited progress.

By applying the seven functions of innovation (Hekkert et al., 2007), this work demonstrates the importance of supporting all innovation functions to create an enabling environment for addressing pest-specific issues at the on-ground level, as opposed to focusing predominantly on producing new technologies.

Reconceptualising farmers and local industries as entrepreneurs (function 1) in the biosecurity innovation system, rather than adopters, opens new pathways for achieving better outcomes. It broadens the focus from a key emphasis on communicating new findings and recommendations to farmers (as is typically done as part of linear thinking), to also seeing local industries as loci of lessons learned based on experimenting in different conditions. Where a lack of adoption in linear thinking is easily addressed by more or better communication to farmers, a lack of entrepreneurial activity signals that there is likely issues with the other functions that hold back uptake (Hekkert et al., 2007). It also includes offering other forms of support, such as ‘smart regulation’.

Broadening knowledge development (function 2) to beyond scientific knowledge development, strengthens the demand for other types of knowledge required to identify workable solutions. This includes farmers’ hands-on learning, practical experience and knowledge of the local context. This means there is a need to strengthen investment in finding and working with such knowledge sources.

Knowledge diffusion (function 3) stresses the importance of multi-directional information flow in the biosecurity arena. This work illustrates that knowledge transfer to some groups, such as risk contributors who have limited incentive to address a biosecurity issue, may have limited effect. To achieve sustained, long term change, more innovative ways to address these sources of pest risks are needed, such as ‘smart regulation’.

Where the international and domestic trade contexts shape the conditions for pest management at the local level, the various knowledge systems within and across levels need to integrate in order to co-produce new knowledge to identify workable solutions (functions 2 and 3). Innovation platforms offer a way to achieve this. Coordinated multi-directional information flow and co-evolution ensure trade conditions can be developed that meet the needs of both farmers and markets. As many stakeholder groups are present throughout the biosecurity system, as is evident from the QFly management innovation system, investment in knowledge brokering is fundamental to overcome cognitive differences and to facilitate a shared language.

There is much evidence in the Australian biosecurity arena of ‘guidance of the search’ (function 4), including a wide range of pest and jurisdiction specific biosecurity strategies or action plans. What this research shows is that in the case of mobile pests where collective action is needed, there is also a need for ‘guidance of the search’ at the local level in the form of a shared vision. Achieving such shared vision can be difficult and can involve high transaction cost, especially in regions where there is heterogeneous on-farm aims. Investment in terms of time, effort and resources is required to achieve this.

Market formation (function 5) for agricultural produce affected by biosecurity is highly regulated. This work illustrates that for biosecurity this function might be met by conservatism. Markets prefer not to experiment with new phytosanitary measures that have not been trialled and tested elsewhere. It suggests that higher investment might be required to create legitimacy for new phytosanitary measures (function 7) than would be expected for innovations beyond biosecurity.

Mobilisation of resources (function 6) is a key challenge for Australian biosecurity where the demands on the biosecurity budget is increasing and government budget cuts are not uncommon (Higgins et al., 2016). In the Australian context, there is scope to further

explore ways to extract financial contributions from people who undertake behaviours that are regarded as risky to biosecurity (Waage and Mumford, 2008). For example, where key risk groups are required to contribute to biosecurity efforts in the form of levies or land taxes, potentially as part of a ‘smart regulation’ package.

Fruit fly AWM demonstrates that for the creation of legitimacy (function 7) of new biosecurity approaches, efforts are needed at both the local level and in the market space to overcome prejudices, concerns and apathy. Where local industries need to take on roles and responsibilities that traditionally rested with government, there is a need for governments to find ways to give local industries legitimacy to do so. In the AWM context this includes dealing with town people and other risk contributors in the region who have little incentive to manage pests. It is important that these groups witness that government (state/territory governments in the Australian context) is backing industry’s efforts. This can come in the form of devolved power, or other forms of ‘smart regulation’, which signals that the pest issue at hand is of prime concern and addressing it is a high priority.

Furthermore, in relation to literature about modern biosecurity approaches, the multi-level system that hangs off the international phytosanitary system presents several challenges. This work illustrates that the local level can easily become disconnected from higher institutional and support levels, manifesting in a range of issues. For example, there can be limited understanding of trade rules relating to a specific pest at the local level. Policy-makers can easily underestimate the challenges for farmers to achieve cooperative pest management. In addition, the multi-stakeholder nature of the pest problems can easily result in a lack of a shared language between stakeholder groups—such as entomologists, market access experts, biosecurity administrators and farmers—challenging knowledge co-production.

In relation to Australia's push for partnerships and shared responsibility, this work demonstrates that several stakeholder groups need to maintain a fine balancing act, in particular all three levels of government. At the local level, state governments need to make trade-offs in meeting the expectations of different agricultural and non-agricultural groups inhabiting the rural space. Following on from the trend towards farmers losing their hegemony in rural areas, state governments tend to be reluctant to force the will of agricultural groups over that of other groups, such as town residents or peri-urban landholders. Likewise, the state/territory governments and the Australian Government need to balance maintaining legitimacy with farmers in their jurisdictions and fulfilling their phytosanitary biosecurity obligations. This means that these government agencies are both the partner and the regulator of local agriculture industries.

#### **5.4 Recommendations for further research**

As this research was based on three case studies, there is room to expand the empirical scope to see if the findings hold in other cases where industry-driven AWM is implemented or attempted. This could assist in identifying other local social factors that influence the feasibility of AWM (beyond those identified in 5.2.1 Principle 1. The local social profile influences the prospects of successful AWM). There are cases in Australia where forms of 'smart regulation' are applied in AWM programs and they can provide insights about the implementation of complementary measures. Currently in Victoria QFly management coordinators are appointed at regional and state level. Much can be learned from this approach by applying an AIS lens.

The research reported here illustrates that market requirements can have a considerable influence on the incentives that local resource users have to manage a resource. Yet it is seldom highlighted in literature about the commons (with some exceptions such as Markelova et al., 2009; Agrawal, 2001) and adaptive co-management, which are

predominantly conservation and environmental management oriented. Further research about how to deal with the market access component of some natural resources is needed. This includes strengthening insights about how to achieve a balance between the need for harmonisation in global biosecurity systems for trade and allowing local programs to adjust to the local context.

More work is needed to understand how to strengthen institutional support for industry-driven AWM programs. This includes how they can be best resourced, including under different circumstances, such as based on the benefits obtained and QFly risk posed by different groups within the AWM region. In addition, a more detailed actor-network analysis will provide deeper insights into how the operation of the fruit fly support and institutional network as a whole can be best strengthened, including in terms of the flow of information and resources. This would be most valuable in informing the design and management of innovation platforms to prevent unnecessary introduction of new structures. A comparative functional-structural analysis between QFly and other successful AWM programs is likely to provide further insights about how QFly AWM programs can be best supported by the broader QFly management AIS. Successful AWM programs include Australia's sugar (Hunt et al., 2012) and cotton (Ferguson and Miles, 2002) industries, or the Hawaii fruit fly AWM program (Vargas et al., 2008).

In the context of partnerships and shared responsibility, there is a need to investigate different forms of devolved power and 'smart regulation' to make local AWM programs more feasible, sustainable and less costly to industry. More research is required about the appropriate and feasible role of local governments in AWM programs, including the capacities and resources they need to support such programs. Most rural towns have residents who are passionate about the QFly cause. Further work can identify volunteer roles, such as possibly assisting with awareness-raising and education, distributing traps and other QFly management materials, trap monitoring, lobbying government and engaging



other businesses and groups for support. Understanding how best to deal with pest pressure from towns will benefit from a more in-depth study about how other countries and their regions deal with this issue. This includes understanding the underpinning logic in terms of how the role of the broader community in biosecurity is conceptualised by building on existing work such as that done by Barker (2010). More broadly, a comparison between Australian practice and how other countries conceptualise the role of government, industry and the community in biosecurity, including the underpinning logic and assumptions, will provide valuable insights into how to best and realistically define roles and responsibility of each partner, including for QFly management.

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## Appendices

## **Appendix 1. Questions for Phase 1 case study interviews**

Note that questions were adjusted depending on who the interviewee was and what his/her role involved.

### **1. Introduction prompts**

- Assurance about confidentiality of information provided
- Obtain permission to record interview

### **2. Tell me more about yourself and how QFly and AWM relate to you.** (Prompts to growers include impacts on production; to growers and supply chain members ask about how does QFly affect market access)

### **3. How does the AWM program operate?**

- Can you briefly explain how the program works? (prompt with how is QFly managed, who does the treatments, what is expected of growers, supply chain members and the town community, etc.?)
- What do you think about what has been achieved to date?
- How are the 'rules of the game' established?
- Are there any consequences for those who do not support the program?
- What are areas of 'hidden cost' for the program, if any?
- What are the main challenges to the success of the program?
- What has been the main enablers of the program so far?

### **4. Let's talk about the players in the AWM program.**

- Who are currently the main players in the program?
- What are growers like in this region?
- What sort of support does the program receive from government agencies?
- What sort of support does the program receive from industry bodies?
- What sort of support does the program receive from supply chain members?
- What sort of support does the program receive from town communities and other landholders?
- Who else do you think should be more involved? Why?

### **5. Now I would like us to explore communication within and about the program.**

- How does communication within the program work?
- How is the program promoted?
- Do growers know who is supportive and who isn't?
- To what extent do growers encourage others to support the program?

## **Appendix 2. List of knowledge, capabilities and resources required for local industries to achieve fruit fly AWM**

### **1. Effective program administration and management**

- Ability to achieve a local shared vision and purpose
- The ability to effectively implement the program cycle:
  - *Planning* – including setting shared vision and goals, developing a strategy and ‘rules of the game’ to achieve them, identifying needs and ways to fulfil them, making trade-offs, etc.
  - *Implementation* – incl. dealing with practicalities and unforeseen circumstances not considered in the planning phase.
  - *Monitoring* – including QFly numbers, uptake of recommended practice, etc.
- The ability to effectively administer the program, including organising regular meetings, developing action points, follow up, minute writing, record-keeping, etc.
- The ability to carry out sound financial management of the program.
- Process skills – Meeting facilitation, negotiation, conflict management, etc.
- The ability to secure start-up and long-term funding, in-kind and other forms of support, including funding for contingencies – effective application writing, networking, relationship-building, etc.
- Understanding broader institutional requirements that might apply, such as public liability and professional indemnity.
- A form of policing to ensure compliance.

### **2. Effective stakeholder interaction**

- Establish combined effort to get all stakeholders on the same page, including to achieve collective action.

- Access to networks to reach key people in the local community, government and other key stakeholder groups and gain their support.
- Implementing effective engagement processes for different stakeholder groups, including the ability to reach large numbers of people without losing sight of the importance of one-on-one engagement.
- The ability to monitor engagement processes to effectively respond to opportunities and issues.
- Understanding the drivers for compliance and non-compliance and how these vary over time, for example, the effect of on-farm QFly pressure, market access requirements, fluctuating commodity prices, etc.
- Increase uptake of recommended practice, including developing incentives for compliance.
- The ability to develop effective engagement materials and tools.
- The engagement of local leader(s) and champion(s) who are able to inspire and maintain motivation and a share vision to underpin local collective action.
- Find workable solutions to deal with other sources of QFly infestation risk, such as derelict orchards and travellers carrying fresh produce into the region.
- Support for growers along the way ('hand-holding and reassurance') while they build their confidence in the system.
- Ability to develop and implement effective conflict management process(es).

### **3. Understanding QFly behaviour and on-ground control in the target region**

#### *Overall*

- Knowledge of QFly biology and behaviour, including host range, temperature thresholds, behaviour, lifecycle, number of generations per year, reproduction and dispersion capacity, the distance QFly travels, etc.



### *Understanding options*

- Understanding QFly behaviour within the target region all year round, its risk pathways and movement. This includes knowing the role of different hosts and alternative food sources for development and survival, timing of fruit ripening of all potential hosts, and maturity stage preference. In practice, typically this would require identifying the location of and describing:
  - the target region's boundaries and sub-regions (e.g. river, non-arable land, forest)
  - QFly host material (size, numbers, type of management), including commercial, backyard, council, abandoned and feral hosts
  - potential QFly overwintering refuges and other hot spots.
- Understanding current on-ground control options and how to prevent QFly moving between locations, including pros and cons of each option and how they relate to the local context. This includes knowing the type, spread, location of existing or planned traps for monitoring, as well as the application of fruit testing, baiting, cover spraying programs, male annihilation technique and sterile insect technique.

### *Ability to implement*

- Ability to consistently implement chosen QFly control methods across the district.

## **4. Market access**

### *Overall*

- Understanding the market access application and approval process, including ways to maximise opportunities and enough understanding of the politics involved to have realistic expectations.
- Understanding the IPPC requirements and guidelines in relation to QFly, the related control approaches and measures and the limitations of IPPC guidance. For example,

guidance about systems approaches involves broad statements whilst details remain under-developed; hence there is variation in how countries interpret them.

- Understanding the expectations of current and potential trading partners.
- Understanding the meaning and impact of various treatment modes of actions and standards (e.g. physical, chemical and irradiation), the concept of probit levels, and the concepts of dependant and independent measures.
- Understanding the importance and limitations of verification activities including inspections, fruit cuts and other methods that might verify various aspects of a pest control program.

#### *Understanding options*

- Understanding the pre- and post-harvest phytosanitary measures available, their pros and cons, e.g. system approaches, trade windows, pest free areas, pest free places of production, areas of low pest prevalence, including relating to setting-up and implementing the measures and the on-going monitoring and verification likely to be expected from trading partners.
- Understanding how to obtain rigorous data, where needed, to demonstrate the effectiveness and efficacy of phytosanitary measures to support a market access application.
- Alternative chemicals, e.g. those registered for use in other commodities or regions, but not registered for QFly.
- Understanding of the documentation requirements relating to different phytosanitary measures, both for the application process and on-going monitoring once accepted and implemented.
- Understanding how to 'package' the above into a workable system, including verification steps.

#### *Ability to achieve and maintain market access*

- Ability to develop an effective market access application.
- Ability to gather information needed to provide scientific evidence of the effectiveness of proposed phytosanitary measures, including possibly engaging third parties to conduct trials to generate the needed data.
- Ability to consistently implement and ensure monitoring of phytosanitary measures.
- Ability to fulfil documentation requirements relating to chosen phytosanitary measures.
- Ability to identify and implement suitable procedures and corrective actions for dealing with non-conformities and non-compliance.
- The ability to consistently produce fruit (in export boxes) that are free from phytosanitary risk.

#### **5. Other**

- Knowledge of the region's QFly management history, including historic data records and QFly behaviour under certain conditions. This might require access to government trap data.
- Knowledge of the region's weather history and how it interacts with trends in QFly populations.
- Understanding government and other stakeholders' logic and policy paradigms that set the context for current decision-making.
- Projected future trends of QFly in the region, e.g. under climate change.
- Stay up to date with new developments in research and development.

### Appendix 3. Grower survey questions

(The Riverina survey is used as an example here)

#### Riverina QFly Grower survey 2015

Many thanks for your willingness to take part in the survey about how Queensland Fruit Fly (QFly) impacts you; what you think about different management methods; and how you view collaboration and support in this area.

1) What is your postcode? \_\_\_\_\_

2) Please rate the impact that QFly has had on your horticulture operation over the last 12 months.

	No impact	Low impact	Medium impact	High impact	Don't know
Produce quality	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Production cost due to the need for on-farm QFly management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to access markets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Production cost due to the need for post-harvest treatments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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**3) How important is the income you get from horticulture as part of your total household income?**

- ☐ High – Most or all of our income comes from horticulture
- ☐ Medium – Horticulture income is important, but other income sources can sustain us
- ☐ Low – Horticulture makes a small or no contribution to our total household income
- ☐ Not applicable, e.g. I am a paid employee of the horticulture business

**4) Which of the following statements best describe the future goals for your horticulture production?**

- ☐ Grow some or all aspects of the horticulture operation
  - ☐ Maintain the current horticulture operation as is
  - ☐ Lessen dependence on horticulture production
- 

**Let's have a look at QFly management practices. We would like to know which ones you apply or have applied in the past. As well, we would like to know what you think about different practices in terms of their effectiveness, practicality and cost.**

**5) Which of the following QFly management activities have been applied in your horticulture operation (or part thereof), either currently or in the past?**

- ☐ Protein baiting
- ☐ Male annihilation technique (MAT)
- ☐ Crop monitoring using traps
- ☐ Picking up fallen fruit
- ☐ Mulching fallen fruit
- ☐ None of these

**6) Have you employed a crop consultant to assist you with QFly management during the last 12 months?**

☐ Yes

☐ No

**7) Would you invest in contract spraying for QFly, if it was available?**

☐ Yes, definitely

☐ Fairly likely

☐ Fairly unlikely

☐ No, definitely not

**8) How do you prefer a contract spraying service to operate?**

☐ The contractor is a packhouse employee and the payments for the service comes out of my delivered produce

☐ The contractor runs in conjunction with the packhouse and the payments for the service comes out of my delivered produce

☐ The contractor is independent from the packhouse and I pay the contractor directly

☐ I have no preference about how such scheme operates

**9) What do you think about QFly trapping as part of monitoring QFly prevalence? Please rate the statements.**

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
Trap monitoring is an effective way that assists in managing QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in trap monitoring as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Trap monitoring makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I know how to do monitoring based on best recommended practice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**10) What do you think about in-field inspections for QFly prevalence? Please rate the statements.**

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
In-field crop inspections are an effective way to prevent QFly damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in in-field crop inspections for QFly as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In-field crop inspections for QFly makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**11) What do you think about bait spraying for QFly? Please rate the statements.**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
Bait spraying is an effective way of managing QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in bait spraying as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bait spraying makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bait spraying causes no quality concerns to produce	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I know how to apply bait spray based on best recommended practice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**12) What do you think about Male Annihilation Technique (MAT) for QFly? Please rate the statements.**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
MAT is an effective way of managing QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in applying MAT as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MAT makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I know how to apply MAT based on best recommended practice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MAT distorts QFly trapping for monitoring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



**13) What do you think about picking-up fallen fruit? Please rate the statements.**

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
Picking-up fallen fruit is an effective way to prevent QFly proliferation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in picking-up fruit as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Picking-up fruit makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**14) What do you think about mulching fallen fruit into the soil? Please rate the statements.**

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
Mulching fallen fruit into the soil is an effective way to prevent QFly proliferation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can easily fit in mulching fallen fruit into the soil as part of other on-farm activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mulching fallen fruit into the soil makes little difference to on-farm cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

a. List the horticulture crops grown for sale on your property during the last 12 months

*Note: The level of QFly management needed for each crop will depend on its susceptibility and growing season. Please base your answer in relation to the recommended best practice for the crop in your area. Here is a guide:*

- c. Crop damage during the last 12 months*

[illegible]

	CROP (write in)	LEVEL OF QFLY MANAGEMENT						LEVEL OF QFLY DAMAGE				PRODUCTION AREA (choose one unit)	
												Acres	Ha
		Highest	Strong	Some	None	Mostly cover sprays	NA - Not susceptible	None	Low	High	Crop destroyed		
3.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
4.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
5.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
6.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
7.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
8.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

16) Do you have other QFly host plants on your land including in your backyard or around sheds? This includes most fruit and vegetables, loquat trees, feijoas, etc.

- ☐ No
- ☐ Yes – What is the overall level of QFly management in the other host plants around your house and sheds?
- ☐ Highest
  - ☐ Strong
  - ☐ Some
  - ☐ None
  - ☐ Rely on cover sprays

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17) Let's look at a view more of your views. How much do you agree with the following statements?

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
QFly infestation on nearby land makes it more difficult to manage QFly on my land	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am actively involved in grower groups where the issue of QFly is discussed from time to time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My level of on-farm profitability has no impact on my level of QFly control	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other on-farm pressures have no impact on my level of QFly control	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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Now we want to know what you think about other people, groups and organisations and their support for QFly management. In particular, do you think they know how to, want to and is able to do what is needed from them?

18) How much do you agree with these statements about full-time growers in your region?

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
All full-time horticulture growers know how to manage QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All full-time horticulture growers are serious about managing QFly on their land	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All full-time horticulture growers are able to manage QFly on their properties, including having the needed money, time and equipment to get it done	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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**19) How much do you agree with these statements about part-time growers (such as people on smaller acreage blocks) in your region?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
All part-time horticulture growers know how to manage QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All part-time horticulture growers are serious about managing QFly on their properties	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All part-time horticulture growers are able of controlling QFly on their properties, including having the needed money, time and equipment to get it done	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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**20) How much do you agree with these statements about QFly pressure from towns.**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
QFly breeding in towns increases QFly pressure for horticulture farms in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All town residents understand the QFly issues faced in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Town residents will sufficiently manage QFly in their yards when there are regular education and awareness-raising activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
QFly treatments on public land are an effective way of reducing QFly pressure in our region (such as baiting, trap monitoring and MAT blocks along town streets)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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**21) How much do you agree with these statements about the Riverina Biosecurity Inc (RBI)?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
RBI knows how to minimise QFly pressure in the Riverina	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RBI is serious about helping us to minimise QFly pressure in the Riverina	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RBI is capable of minimising QFly pressure in the Riverina (including having the needed funding, influence, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have a good understanding of what RBI does	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**22) How much do you agree with these statements about your local council (local government)?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
The Council knows how to minimise QFly pressure in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Council is serious about helping us to minimise QFly pressure in our region with the resources they have	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Council is capable of minimising QFly pressure in our region (including the needed funding, influence, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Council knows how to minimise QFly pressure in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**23) How much do you agree with the statements below about the New South Wales Department of Primary Industries (NSWDPI)?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
NSWDPI knows how to minimise QFly pressure in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NSWDPI is serious about helping us to minimise QFly pressure with the resources they have	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NSWDPI is capable of supporting us to minimise QFly pressure (including having the needed staff, funding, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NSWDPI is helping us to help ourselves to overcome our QFly problems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**24) How much do you agree with the statements below about the Local Land Services?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
LLS knows how to minimise QFly pressure in our region	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LLS is serious about helping us to minimise QFly pressure with the resources they have	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LLS is capable of supporting us to minimise QFly pressure (including having the needed staff, funding, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LLS is helping us to help ourselves to overcome our QFly problems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**25) Who do you believe is the most appropriate group for overseeing on-ground QFly control in your region?**

- ☐ Government, the issue is beyond the control of industry
  - ☐ Government and industry, but government with all its powers need to take the lead
  - ☐ Industry and government, but industry as the most affected party needs to take the lead
  - ☐ The horticulture growers impacted by QFly
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**Let's talk about QFly and market access ...**

**26) Are you, or are you interested in, supplying citrus to QFly-sensitive markets?**

- ☐ Yes
- ☐ No – *Please skip to question 32 on p16.*



**27) How much do you agree with the following statements?**

*Note: Area-wide management refers to coordinated pest management across a region, including on farmland and in towns.*

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
I understand what is meant by using a systems approach for market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I understand what an 'Area of Low Pest Prevalence' means in the context of market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Area-wide management is the way of the future to manage QFly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
An 'area of low pest prevalence' is valuable in negotiating domestic market access as part of a systems approach	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
An 'area of low pest prevalence' is valuable in negotiating international market access as part of a systems approach	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**28) How much do you agree with these statements about the role of Riverina Biosecurity Inc (RBI) in strengthening market access?**

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree	Don't know
RBI understands the QFly-related issues that hinder our market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RBI is serious about helping growers overcome QFly-related barriers to market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RBI is capable of making a significant difference to reducing QFly-related barriers to market access (including working with the right government people)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**29) How much do you agree with these statements about Citrus Australia?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
Citrus Australia understands our QFly-related issues that hinder market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Citrus Australia is serious about helping our local industry overcome the QFly-related issues that hinder market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Citrus Australia is capable of supporting our local industry to overcome the QFly-related issues that hinder market access?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**30) How much do you agree with these statements about NSW DPI?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
NSW DPI understands our QFly-related issues that hinder market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NSW DPI is serious about helping our local industry overcome the QFly-related issues that hinder market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NSW DPI is capable of supporting our local industry to overcome the QFly-related issues that hinder market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**31) How much do you agree with these statements about the Australian Government Department of Agriculture (DoA) in Canberra?**

	<b>Strongly disagree</b>	<b>Somewhat disagree</b>	<b>Somewhat agree</b>	<b>Strongly agree</b>	<b>Don't know</b>
DoA understands our QFly-related issues that hinder our overseas market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DoA is serious about helping our local industry overcome the QFly-related issues that hinder overseas market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DoA is capable of supporting our local industry to overcome the QFly-related issues that hinder overseas market access	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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**About your information sources for QFly management...**

**32) Where did you learn about QFly? Please mark your top two sources.**

- ☐ DPI officers
- ☐ Grower meetings
- ☐ Fellow growers
- ☐ Internet searches
- ☐ DPI Print material
- ☐ Other print material
- ☐ Chemical company

*....Please turn over....*

- ☐ Private consultant
- ☐ Pesticide supply store
- ☐ The recent fruit fly campaign by RBI/LLS
- ☐ The Fruit Fly Coordinator (Tammy Galvin)
- ☐ Other – Write In: \_\_\_\_\_

**33) If you had QFly-related questions now, where would you look for information? Mark your top two sources.**

- ☐ NSW DPI officers
  - ☐ Grower meetings
  - ☐ Fellow growers
  - ☐ Internet searches
  - ☐ NSW DPI Print material
  - ☐ Other print material
  - ☐ Chemical company
  - ☐ Private consultant
  - ☐ Pesticide supply store
  - ☐ Local Land Services
  - ☐ Riverina Biosecurity Inc. member
  - ☐ The Fruit Fly Coordinator (Tammy Galvin)
  - ☐ Other – Write In: \_\_\_\_\_
-

## **A bit more about yourself...**

### **34) What is your highest level of formal education?**

- ☐ Primary school
- ☐ Part secondary school
- ☐ Secondary school
- ☐ Trade/technical certificate
- ☐ Diploma/Associate diploma
- ☐ Degree
- ☐ Postgraduate

### **35) How old are you?**

- ☐ 18-30 years
- ☐ 31-45 years
- ☐ 46-60 years
- ☐ 61 years and older

36) Do you have any other remarks you would like us to be aware off?

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Thank you for taking our survey. Your response is very important to us.

## Appendix 4. Phase 2 interview questions

### Introduction prompts:

- Assurance about confidentiality of information provided
- Obtain permission to record interview

### Background

- 1) Please tell me about yourself and your role and how it relates to QFly management.

### Current role

- 2) What is your understanding of your organisation's role in the challenge of QFly?
- 3) What is your understanding of your organisation's role in advancing on-ground QFly control, for example, in assisting local industries to achieve a form of AWM?
- 4) What is your understanding of your organisation's role in advancing market access for local industries where QFly is a market access barrier?
- 5) What are the main barriers to your organisation providing support to local industries in relation to AWM?
- 6) From your perspective, what are the key knowledge and capabilities that local industries need to achieve AWM (*ignoring for a moment the list that I sent through*)?
- 7) What do you think is the potential for AWM as part of a systems approach to underpin market access?
- 8) What are the key knowledge, capabilities and resources that local industries need to achieve access to QFly-sensitive markets using a systems approach involving AWM (*ignoring for a moment the list that I sent through*)?

### Verification of knowledge, capabilities and resources list

Here is a draft list of knowledge, capabilities and resources that I put together based on previous interviews, focus groups and literature. (*Show list. If interviewee mentioned capabilities, knowledge or resources not on list, acknowledge them with a promise to add them*).

- 9) Are there any other knowledge, capabilities or resources you would like to add?
- 10) Are there any knowledge, capabilities or resources listed that you disagree with?

### Potential role

- 11) Based on this list, in which of these areas, besides what you already mentioned, do you believe your organisation can potentially support local industries?
- 12) How can local industries secure that support?

### Conclusion

- 13) Is there anything else you would like to add?